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Earth Resources Data Acquisition Sensor Study

Period: December 1, 1974 - May 31, 1975

Final Technical Report
Contract NAS8-31169

by

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Prepared for

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National Aeronautics and Space Administration
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Abstract

This preliminary study concerns itself with the investigation of the minimum data collection and data processing requirements for the development of "smart" water monitoring systems, which disregard redundant and irrelevant data and process only those data predictive of the onset of significant pollution events. Two approaches are immediately suggested: 1) adaptation of a presently available "smart" ambient air monitoring system developed by TVA, and 2) consideration of a "smart" air, water, and radiological monitoring system developed by the Georgia Tech Experiment Station. In order to apply "smart" monitoring systems, threshold values and maximum allowable rates of change of critical parameters such as dissolved oxygen and temperature are required. Hopefully, these will be determinable through STORET and other sources of water quality data, which are presently being investigated.

Introduction

The broad objective of this study was to investigate the requirements for the establishment of prediction models of rivers and streams based upon the use and correlation of data obtained with ground contact sensors such as obtainable with ERTS data collection platforms employing Hydrolab sondes (multiple sensors) as well as remotely sensed data obtained with the use of satellites and aircraft. The specific objective of this project was to investigate "smart" water monitoring systems, which discriminate and reject redundant and experimentally meaningless data and treat and correlate only those data predictive of the onset of significant water pollution events.

This report summarizes the initial study effort, which was 1) to review and assess what has been done and what is currently being done in this general investigative area and 2) to recommend how the latter may be applied to the objectives of the present and possible future studies.

First, a literature search was initiated which produced Environment Index abstracts of articles relating to the topics or areas listed in Table I. These abstracts were reviewed and copies of selected articles then obtained from the Redstone Scientific Information Center or ordered through the University of Alabama in Huntsville Library. (The latter have not yet been received). The articles obtained were then studied in greater depth. Those considered to be pertinent to the objectives of the present study were abstracted (See Appendix A). Those articles reviewed but concluded not to be directly or immediately pertinent to the present study were not abstracted but are simply listed by title in Appendix B.

Concurrent with the literature search, meetings and/or telephone discussions pertaining to the objectives of the present study were held with

representatives of various organizations concerned with water pollution control. These are listed in Appendix C. Various leads and suggestions were obtained from the above discussions. Those of most immediate interest were as follows:

1. The Air Quality Branch of TVA at Muscle Shoals has developed (with contractor assistance) a sulfur dioxide emission limitation program (SDEL) for monitoring and controlling pollution from its steam plants. The approach parallels the objectives of the present study with respect to economical procurement and treatment of data. TVA provided some documentation of their program, and Mssrs. John Frey and Robert Imhoff were visited at Muscle Shoals on April 15, 1975 for the purpose of discussing possible adaptation of this approach to water pollution control applications. A discussion of the SDEL approach and its possible adaptation to the objectives of the present study are given on pp. 4-7.

2. The Engineering Experiment Station of Georgia Institute of Technology has developed (under contract with the Department of Administrative Services - State of Georgia) what Mr. Tom Miller of Georgia Tech termed during our telephone discussion a "smart" remote data acquisition system. The Department of Administrative Services of the State of Georgia is presently applying or is planing to apply the system to water and radiological pollution control as well as to air pollution control. A brief description of this system, just received, is given in Appendix E.

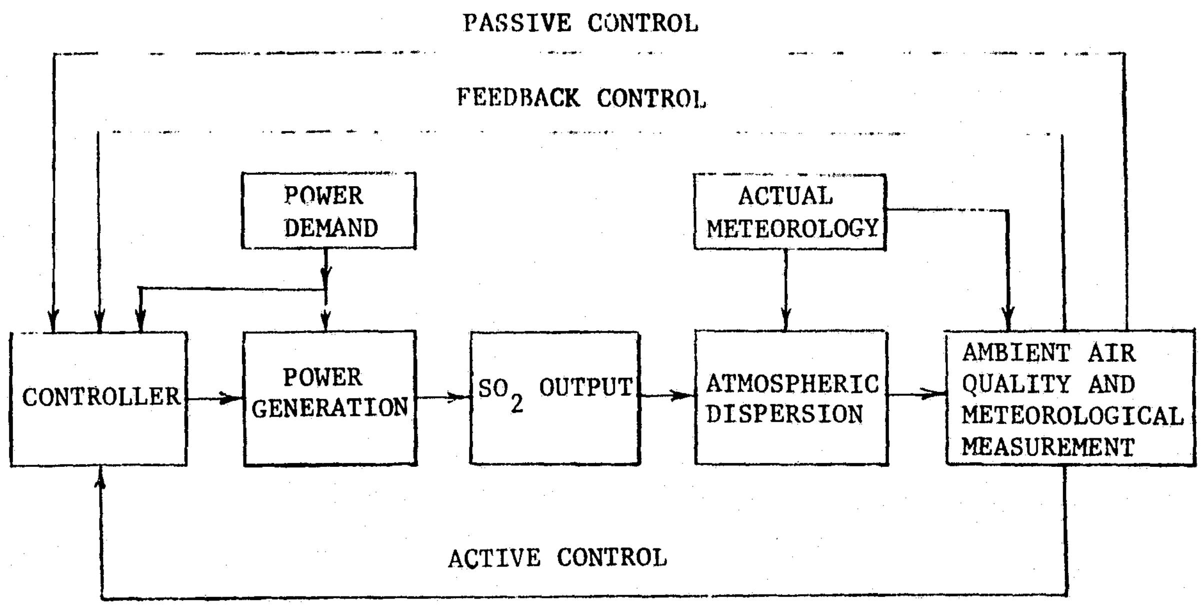
3. Arrangements have been made with Mr. Wilburn Holsomback of EPA (Athens, Ga.) to send us whatever STORET water data we might find useful for our studies. For example, we have already received summarized statistical ("inventory") data obtained from all stations along the Tennessee River between Wheeler Dam and Widow's Creek Steam Plant as well as from stations along selected tributaries, such as Indian Creek and Flint River. An abridged summary of these data is given in Table II. We have subsequently requested complete ("raw") STORET data for selected stations between Wheeler Dam and Guntersville Dam for purposes stated later.

Although many of the articles of possible interest have not yet been received, and further study of the articles abstracted in Appendix A is merited, the most interesting approach uncovered to date with respect to possible adaptation to the development of a "smart" water monitoring system is that underlying TVA's SDEL program which is, in effect, a "smart" ambient air monitoring system.

TVA SDEL Program

The SDEL program was developed for the purpose of monitoring and controlling SO_2 from TVA's coal-fired power plants in order to meet EPA's ambient air quality standards in hope that this will suffice and that EPA's SO_2 emission standards will not have to be met as well, which would require wide-spread, expensive installations of SO_2-removal equipment. The SDEL program is concerned only with the control of SO_2; particulates are evidently capable of being controlled at acceptable levels through the use of electrostatic precipitators.

A conceptual diagram of the SDEL program is shown below. A more detailed flow diagram is given in Figure 1.



Referring to the above diagram, electric power is ordinarily generated (i.e., coal is burned and SO_2 emitted) in accordance with consumer demand. However, power generation cannot be increased without limit, regardless of demand, because of EPA limitations on ambient SO_2 concentrations. This is true whether or not the EPA limitations of SO_2 emissions will eventually have to be complied with as well. By means of the SDEL program, the ambient SO_2 concentration standards are met with as follows:

For a given rate of power generation, SO_2 is emitted at some corresponding rate. It is then dispersed in accordance with the meteorological conditions at the steam plant and its surroundings. Following dispersion, the ambient air meteorological conditions and SO_2 concentrations are measured and the data fed to the controller (represented by Block 1, 2, and 3 in Figure 1) via any and all of the three control loops shown in the conceptual diagram. Normally, feedback control suffices, wherein the ambient

SO_2 concentrations and the measured meteorology are compared with the allowable (threshold) SO_2 concentrations and allowable (threshold) rates of change of the ambient SO_2 concentrations, which threshold values are dependent upon the measured (present) meteorology*. As long as neither the threshold concentrations nor the threshold rates of change are exceeded, the rate of power generation (as controlled by Box 3 in Figure 1) is limited only by consumer demand.

However, if either the threshold concentrations or rates of change are approached, the Active Control Loop takes over before a control decision is made regarding possible reduction in the rate of power generation. For example, a stagnant meteorological condition may be shortly displaced by one of high dispersion (which might not be forecast by simply following the existing meteorology) whereupon both the values and the rates of change of SO_2 concentration would rapidly decrease, no longer making it necessary to reduce power operation. Therefore, as soon as the active control loop takes over, predictions are made of the meteorological conditions and threshold values for the immediate and near future, against which the current ambient SO_2 concentrations and rates of change are subsequently compared. The active control loop primarily involves manual inputs to the controller. The controller itself consists of a built-in mathematical model with threshold values and rates fed into it via the feedback control loop. Four-to eight-hour predictions of meteorological conditions are manually fed into the controller along with the existing meteorological conditions. The active control loop interrogates the feedback control loop results and then reaches a control decision as to whether or not to reduce power generation.

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* Threshold concentrations would be somewhat less than the maximum allowable ambient air SO_2 concentrations as promulgated by EPA.

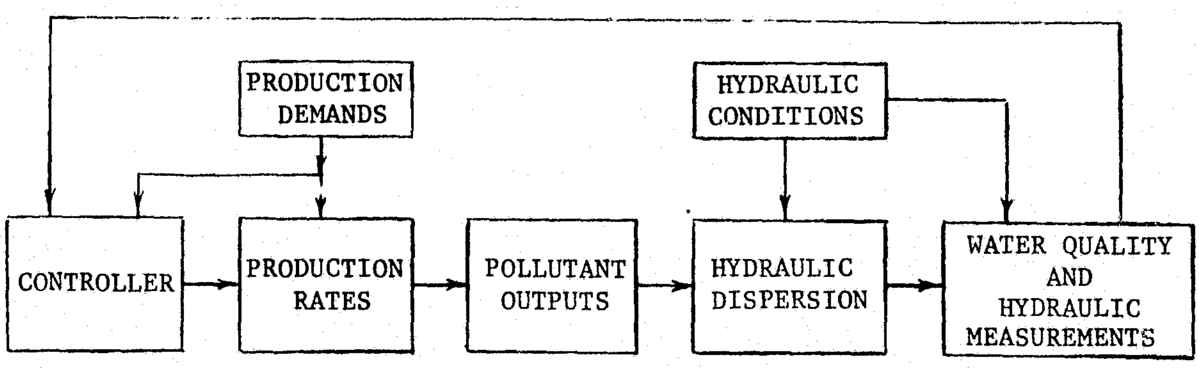
The Passive Control Loop does not enter into day-to-day operations. It simply provides for a yearly update of the logic and basic data in the controller, based upon the previous year's performance of the SDEL program.

The key data required for satisfactory operation of the SDEL program (or of an adaptation to water pollution control) are the threshold SO_2 concentrations and rates of change. These have to be selected on the basis of careful statistical analyses of previous meteorological and SO_2 data.

Proposed Adaptation of SDEL Approach to Water Pollution Control

A simplified conceptual diagram applying the SDEL program approach to pollution control of rivers and streams is given below.

FEEDBACK CONTROL



This control scheme differs in essentials from the SDEL approach only inasmuch as that the passive control loop is not shown and an active control loop is presently considered to be optional, since the relatively sudden major changes in ambient conditions due to sudden major meteorological changes that can occur in an atmospheric environment seem much less likely to occur in a river or stream environment. (However, the effects of sudden precipitation needs to be considered.) Further comparing the two conceptual diagrams, the major additional difference is that in the case of the SDEL

program only a single pollution parameter, SO_2, is involved whereas in the proposed "smart" water pollution control concept at least two pollutant parameters, dissolved oxygen (DO) and temperature and probably at least a third, such as biological oxygen demand (BOD), would be involved, which would doubtless result in a considerably more complicated mathematical model.

Actual application of the above concept would proceed approximately as follows: 1) Threshold concentrations and rates of change of the controlling parameters involved would be established from the available historical pollutant and hydrological data (hopefully STORET and related available data will suffice). 2) By means of an appropriate mathematical model. pollutant concentrations and rates of change and corresponding hydraulic data would then be compared with the derived threshold values and control decisions arrived at to determine the rates at which various pollutant sources can be discharged while keeping in compliance with established water quality standards. This methodology could possibly be improved upon by introducing predicted future hydrological conditions against which present water quality and hydrology might be compared (that is, by introducing an active control loop analogous to that included in the SDEL program). In this way the receiving capacity of a given river or stream system could be optimized.

Discussion

The literature search and study has revealed (as expected) that water quality study programs, including improved methodology for data acquisition and subsequent handling, have increased both in quantity and scope. Rigorous treatment of water quality data is complicated because of the many underlying factors which influence water quality. Furthermore, these factors are random in nature. Consequently, for future time predictions of water quality, the application of statistical techniques is essential.

It has been suggested that in order to properly describe a river-water quality in the light of present-day knowledge, the measurement of some 60 parameters is required*. That many parameters are involved is borne out by Table III, which lists the as many as 86 river water quality and related parameters included on a standard printout of STORET "inventory" (statistically summarized) data. However, relatively few sampling stations on the Tennessee River, for example, report all these parameters, many of which appear non-pertinent to the present study.

Although many parameters must be monitored and analyzed in order to completely describe the water quality of a river or stream, for ordinary pollution control purposes much fewer parameters need to be monitored. For example, if the sources of pollution are predominantly domestic wastes, the monitoring of dissolved oxygen (DO), the five-day biological oxygen demand (BOD)**, and probably temperature will likely suffice. In the event of concern over the possible presence of infectious diseases such as typhoid fever, the additional monitoring of coliforms would be called for. If power plant

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* R. B. Bussell, Process Biochemistry, pp. 32-33 (March 1973). In this reference, the statement was also made that it would be desirable, although presently not possible, to monitor about 16 parameters on a continuous basis.

** According to Dr. Jack Brown of the University of North Alabama, Total Organic Carbon (TOC) is a more useful parameter than BOD for monitoring the Tennessee River.

or other heated-water discharges are of concern, the monitoring of temperature becomes especially important. If toxic industrial or agricultural pollutants are permitted to enter a river or stream, these pollutants must also be monitored, particularly those having a significant probability of exceeding maximum allowable concentrations on occasion.

Dissolved oxygen is probably the most important single water quality parameter. It is physically dependent primarily upon temperature and hydraulic conditions (e.g., turbulence). It is chemically dependent upon oxygen-consuming parameters, such as BOD and chemical oxygen demand (COD), as well as upon photosynthesis. Dissolved solids affect the solubility of gases (such as oxygen) in water, but probably not to a significant extent in the concentrations usually present in rivers and streams. For example, gases such as nitrogen, carbon dioxide, and hydrogen are only 70 to 80 per cent as soluble in one-normal aqueous solutions of dissolved salts such as lithium chloride and sodium sulfate as they are in pure water. However, a one-normal solution of lithium chloride corresponds to roughly 40,000 ppm of dissolved solids, whereas the concentration of dissolved solids in the average river or stream is only of the order of 100 to 300 ppm. Therefore, the effects of water quality parameters which do <u>not</u> consume oxygen (which comprise most of the parameters monitored in the Tennessee River, for example) upon the concentrations of dissolved oxygen in a river or stream would be expected to be insignificant.

The minimum data collection and correlation requirements for the development of river and stream pollution prediction models, therefore, depends upon the pertinent pollution parameters involved. These depend upon the purpose for which the water is used. For example, Appendix E is an excerpt

taken from the Alabama Water Quality Criteria*. In order to establish "smart" monitoring systems, it is necessary to establish maximum threshold values and maximum allowable rates of change of the critical parameters being monitored in a given river or stream. This requires a considerable amount of data. Arrangements have, therefore, been made to obtain complete (raw) STORET data for selected stations along the Tennessee River between Wheeler Dam and Guntersville Dam, with the hope that these data will be sufficient to derive the threshold values and rates required to adapt the SDEL approach to the prediction of future-time pollution events in the Tennessee River. Hopefully, these data will have been determined at equal time intervals, which will greatly simplify determining and applying the threshold values, which are expected to be difficult, at best, since the SDEL program developed by TVA concerns itself with only one pollution parameter (SO_2) whereas it is expected that a minimum of at least several pollution parameters (probably DO and temperature as a bare minimum) would be required for any "smart" water monitoring system. In addition to data such as included in Table II, river flow (hydraulic) data will also be required, and these have been requested.

A "smart" monitoring system will sense but not process data so long as the threshold concentrations and rates are not reached or exceeded. If one or the other are reached or exceeded, the controller will then seek a control decision, following which one or more pollutant sources (industrial and/or domestic) might have to be reduced in a manner similar to the SDEL program wherein the rate of power generation may be reduced in order to restrict the emission of SO_2.

* From Waste Source and Water Quality Studies, Mobile River and Tributaries, Mobile, Alabama, Report EPA-904/9-74-005, Environmental Protection Agency, Surveillance and Analysis Division, Athens, Georgia (Feb. 1974).

In the approach presently being considered, the objective will be the prediction of near-future concentrations of selected parameters at selected stations. Once this is accomplished for selected times, predictions of these same parameters at other stations upstream or downstream of a given station should be predictable by stream and river models already available, such as DOSAG or QUAL-I presently used in Alabama and elsewhere.

Summarized Water Quality Data for Tennessee River

Table II summarizes up to 29 parameters for 26 stations along the Tennessee River between Wheeler Dam and the Widow's Creek Steam Plant. Actually, STORET contains data for a total of 71 stations between Wheeler Dam and the Widow's Creek Station as well as for virtually all, if not all, of the tributaries between these stations. However, for the Tennessee River stations not reported in Table II and for the tributaries, only a relatively few parameters have been reported and these quite infrequently.

Further referring to Table II, the first number in a given box is the average of all of the data obtained for the indicated parameter at the indicated station. Beneath this is the range or minimum and maximum of the values determined. Below this are the total number of determinations of the given parameter and the time period over which they are made. Table II obviously does not include the vast amount of temperature data taken at the Browns Ferry Nuclear Plant over the past several years. These, presumably, would be obtainable directly through TVA.

Conclusions and Recommendations

The broad objective of this study was to investigate the minimum data collection and processing requirements for the development of "smart" water monitoring and management systems. The following summarizes the findings, conclusions, and recommendations based upon the initial six-month study period.

A literature study indicated vastly increased interest in optimal monitoring of receiving waters, such as rivers and streams. The most significant articles and reports reviewed to date are abstracted in Appendix A, and these warrant further study. Many more references (available neither at the Redstone Scientific Information Center nor at the University of Alabama in Huntsville) have been ordered. These should be reviewed as soon as available. Other references of secondary or future interest are listed simply by title in Appendix B.

Discussions were held with representatives of various organizations concerned with water pollution and its control (Appendix C). Statistically summarized water quality data for the Tennessee River between Wheeler Dam and the Widow's Creek Power Plant were obtained from the STORET data bank and are presented in abridged form in Table II.

On the basis of the findings of the initial six-month study period reported herein, two approaches to the above-stated objective are immediately suggested: 1) adaptation of a "smart" ambient air monitoring system developed by TVA for pollution control of its coal-fired power plants, and 2) in-depth study of the "smart" air, water, and radiological data acquisition system developed by the Georgia Tech Experiment Station for the Department of Administrative Services, State of Georgia, for possible

application to the objectives of the present study. Since preliminary documentations on the latter have just been received (without opportunity for significant study thereof), major consideration to date has been given to adaptation of the TVA approach referred to above. The following recommended work plan (temporarily supported by the Center for Environmental and Energy Studies - UAH) is presently being pursued.

The recommended approach requires the determination of threshold values of concentrations and rates of change of concentrations of the controlling pollutants, such as dissolved oxygen and temperature, upon which water quality for a given water usage depends. These threshold values hopefully will be determinable from already available data such as obtainable from STORET, and this possibility is presently being investigated. This information will then be applied to a time-dependent stochastic mathematical model containing the controlling pollutant and flow parameters, the model to be developed independently if not adaptable from an available model. Future concentrations of the critical pollutants, at a specific monitoring station, should thereby be predictable. Future pollutant concentrations at other locations downstream or upstream of the monitored location(s) would then, hopefully, be predictable using existing steady-state models. This entire approach would then be tested by means of water quality data hopefully available in addition to that required for the determination of the threshold values.

In summary, the approach upon which future work is planned requires: 1) identification of the critical pollution parameters to be monitored and controlled for a given water usage and location, 2) development (or adaptation) of an appropriate stochastic model, 3) determination of the necessary

threshold values, 4) prediction of future pollutant concentrations at a given monitoring station by means of the stochastic model, 5) prediction of future pollutant concentrations at other stations using an available or modified steady-state model, and 6) testing of the entire approach via existing water quality data or via new data to be determined with the aid of data collection platforms, for example.

Acknowledgement

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The additional support of a graduate student, Mr. Yedulla R. Reddy, was provided by the Mechanical Engineering Department, the Center for Environmental and Energy Studies, and the School of Graduate Studies and Research. Mr. Reddy's indispensable assistance is gratefully acknowledged, as are the valuable cooperation of Dr. Jerome J. Brainerd, Chairman of the Mechanical Engineering, Drs. Kenneth E. Johnson and Bernard J. Schroer Director and Assistant Director of the Center for Environmental and Energy Studies, respectively, and Dr. J. Edwin Rush, Jr., Dean of the School of Graduate Studies and Research.

An undergraduate student assistant, Mr. Michael DeFiore assisted in the literature search, and Ms. Linda Wunderman typed this report.

Table I - Literature Search Areas

Economics, Environmental - Water

Environmental Data

Estuaries

Instruments

Mathematical Models - Water

Measurements and Sensing

Monitoring - Environmental - Water

Remote Sensing

Rivers and Waterways

Systems Analysis

Thermal Pollution - Water

Water Analysis

Water Chemistry

Water Pollution

Water Pollution Control

Water Pollution Indicators

Water Pollution Instruments

Water Pollution Research

Water Quality Standards

Water Resources Management

Water Temperature

	PARAMETER	UNITS	277.98 (3)	281.67	283.94	288.78	291.76	293.7
1	Temperature	°C	16.6 (2) (3.6-30) 235 (1/70-1/75)	16.8 (4-30) 300 (1/70-4/73)	17.1 (4.5-30) 360 (1/70-1/75)	16.3 (4-29) 122 (1/70-1/75)	16.8 (5-30) 175 (1/70-1/75)	16.9 (4.5-29.3) 157 (1/70-1/75)
2	Turbidity	Jackson Turbidity Units		13.1 (3-35) 79 (4/70-4/73)	14.4 (3-60) 126 (4/70-1/75)		15.4 (3.3-39) 15 (7/73-1/75)	8.5 (7-10) 2 (10/3/73)
3	Conductivity	mho/cm	150 (120-180) 12 (1/73-7/74)	173.2 (110-300) 79 (4/70-4/73)	161.4 (110-220) 156 (4/70-1/75)	146.6 (140-180) 6 (1/73-7/74)	146.8 (130-170) 28 (1/73-1/75)	147.5 (140-180) 16 (1/73-7/74)
4	Dissolved Oxygen (DO)	mg/ℓ	8.9 (1-13.6) 234 (1/70-1/75)	9.1 (1.9-13.5) 314 (1/70-4/73)	8.7 (0.3-13.4) 352 (1/70-1/75)	9.0 (5.4-13) 115 (1/70-1/75)	8.8 (5.6-13) 157 (1/70-1/75)	8.7 (4.8-13) 142 (1/70-1/75)
5	Biological Oxygen Demand (BOD_5)	mg/ℓ		1.6 (1.0-4.4) 82 (1/70-4/73)	1.4 (1-3.2) 129 (1/70-1/75)		1.1 (1-2) 15 (7/73-1/75)	1.1 (1-1.5) 4 (10/73-1/74
6	Chemical Oxygen Demand (COD)	mg/ℓ		6.8 (1-14) 78 (4/70-4/73)	6.5 (1-14) 126 (4/70-1/75)		6.5 (5-10) 15 (7/73-1/75)	6 (5-8) 4 (10/73-1/74
7	pH		7.0 (6.2-7.6) 15 (7/72-7/74)	7.3 (6.3-8.3) 79 (4/70-4/73)	7.3 (6-9) 157 (4/70-1/75)	7.2 (6.6-7.6) 10 (7/72-7/74)	7.1 (6.5-7.7) 32 (7/72-1/75)	7.1 (6.5-7.6) 21 (7/72-7/74)
8	Alkalinity	mg/ℓ	56.1 (49-61) 6 (7/72-4/73)	52.2 (38-63) 79 (4/70-4/73)	52.4 (38-83) 127 (4/70-1/75)	55.2 (51-59) 5 (7/72-4/73)	51.8 (44-60) 20 (7/72-1/75)	52.5 (43-60) 10 (7/72-1/74)
9	Total Organic Carbon (TOC)	mg/ℓ			2.6 (1.5-6.3) 6 (1/8/75)		2.5 (2.0-2.9) 2 (1/9/75)	
10	Total Hardness	mg/ℓ		64.7 (37-110) 79 (4/70-4/73)	65.2 (35-100) 126 (4/70-1/75)		67.1 (62-75) 15 (7/73-1/75)	

FOLDOUT FRAME /

MAJOR WATER QUALITY PARAMETERS(1)
(TENNESSEE RIVER BETWEEN WHEELER DAM AND WIDOW'S CREEK

RIVER MILES FROM OHIO RIVER

293.88 (4)	295.87	301.06	306.0 L (5)	307.52	324.0 (6)	349.0 (7)	363.2	
21.0(4) (12.3-26) 5 (7/72-4/73)	16.9 (4.8-29.6) 142 (1/70-1/75)	16 (4.6-29.7) 77 (1/70-4/73)	19.0 (10-28.9) 7 (8/73-1/75)	17 (4.7-28.8) 137 (1/70-1/75)	27.3 (27-27.5) 2 (9/72)	17.6(7) (4-29) 243 (1/70-1/75)	26.9 (25.9-28.5) 42 (7/70-8/71)	26 (2 39 (7
	12.4 (3.5-35) 22 (1/73-1/75)		35.9 (5-180) 7 (8/73-1/75)			10.6 (1.7-25) 17 (1/73-1/75)	13.6 (9-25) 15 (7/70-8/71)	15 (6 15 (7
	147 (130-170) 30 (1/73-1/75)	430 (430) 1 (1/17/73)	162.9 (150-180) 7 (8/73-1/75)	153.3 (150-160) 3 (1/73-4/73)		153.5 (110-190) 17 (1/73-1/75)	216 (180-240) 15 (7/70-8/71)	21 (1 15 (7
8.0 (7.3-9.3) 4 (7/72-4/73)	8.6 (4.5-12.9) 128 (1/70-1/75)	8.6 (4.2-12.7) 72 (1/70-4/73)	7.9 (5-11.9) 7 (8/73-1/75)	8.4 (5.2-12.9) 123 (1/70-1/75)	5.9 (5.8-6) 2 (9/72)	8.6 (4.7-14.2) 238 (1/70-12/74)	7.4 (5.4-11.3) 34 (7/70-8/71)	7. (5 32 (7
	1.1 (1-1.7) 22 (1/73-1/75)		1.2 (1-2.4) 7 (8/73-1/75)		2.0 (2.0) 1 (9/14/72)	1.1 (1-1.2) 2 (7/73-11/73)	2.0 (1.1-4.8) 15 (7/70-8/71)	1. (1 15 (7
	6 (3-10) 22 (1/73-1/75)		7.4 (4-17) 7 (8/73-1/75)			5.3 (2-8) 17 (1/73-1/75)	6.1 (4-10) 10 (7/70-8/71)	6. (5 10 (7
	7.1 (6.5-7.7) 33 (7/72-1/75)	6.6 (3.3-7.4) 6 (7/72-4/73)	6.9 (6.7-7.2) 7 (8/73-1/75)	7.3 (6.7-7.8) 6 (7/72-4/73)		7.4 (6.6-7.8) 17 (1/73-1/75)	7.7 (7-8.9) 15 (7/70-8/71)	7. (7 15 (7
	52.6 (43-59) 25 (7/72-1/75)	44 (0-54) 6 (7/72-4/73)	51.4 (43-58) 7 (8/73-1/75)	52.3 (37-59) 6 (7/72-4/73)		53.7 (35-120) 17 (1/73-1/75)	57 (50-62) 15 (7/70-8/71)	56 (5 15 (7
	2.1 (0.9-3.3) 4 (7/74-1/75)		2.9 (1-5.6) 7 (8/73-1/75)			2.0 (1.2-2.7) 6 (7/73-12/74)	2.7 (2.2-3) 15 (7/70-8/71)	2 (1 (
	66.4 (62-73) 22 (1/73-1/75)		68.4 (66-73) 7 (8/73-1/75)			63.1 (51-75) 17 (1/73-1/75)	65.3 (51-83) 15 (7/70-8/71)	6 (1 (

RS[1]

OW'S CREEK POWER PLANT)

ER

363.2	365.0	368.3	368.6	369.0	369.4	370.0	370.7
.9 5.9-28.5) /70-8/71)	26.8 (25.8-28.4) 39 (7/70-8/71)	26.3 (25.3-27.1) 4 (7/01/74)	24.9 (24.1-26.2) 16 (7/1/74)	26.1 (25.2-26.9) 4 (7/1/74)	17.3 (6.9-26.5) 18 (8/74-2/75)	17.1 (6.9-26.4) 96 (8/74-2/75)	18.9 (6.8-27) 17 (8/74-2/75)
.6 -25) /70-8/71)	15.7 (6-45) 15 (7/70-8/71)	5.8 (5.8) 1 (7/1/74)	11.5 (5.3-38) 8 (7/1/74)	7.3 (7.3) 1 (7/1/74)	8.7 (4.5-23) 9 (8/74-1/75)	9.5 (2.9-37) 46 (8/74-1/75)	9.9 (5.4-22) 7 (8/74-1/75)
6 80-240) /70-8/71)	215 (180-240) 15 (7/70-8/71)	150 (150) 1 (7/1/74)	140 (120-150) 8 (7/1/74)	140 (140) 1 (7/1/74)	173.3 (160-180) 6 (9/74-12/74)	166.7 (150-180) 33 (9/74-1/75)	173.3 (160-180) 6 (9/74-12/74)
4 .4-11.3) /70-8/71)	7.3 (5.1-10.1) 32 (7/70-8/71)	9.4 (9.4) 1 (7/1/74)	6.9 (5-9.1) 14 (7/1/74)	9.1 (9.1) 1 (7/1/74)	8.8 (6.8-11.3) 15 (8/74-2/75)	8.7 (5.8-11.8) 92 (8/74-2/75)	8.2 (6.8-11.3) 14 (8/74-2/75)
0 .1-4.8) /70-8/71)	1.5 (1-2.5) 15 (7/70-8/71)				1.1 (1.1) 1 (11/5/74)	1.16 (1.0-1.7) 8 (11/5/74)	1.4 (1.4) 1 (11/5/74)
1 -10) /70-8/71)	6.2 (5-8) 10 (7/70-8/71)	7 (7) 1 (7/1/74)	5.4 (4-8) 8 (7/1/74)	4 (4) 1 (7/1/74)	5.3 (3-10) 7 (8/74-1/75)	7.1 (2-39) 46 (8/74-1/75)	5.4 (9-3) 7 (8/74-1/75)
7 -8.9) /70-8/71)	7.6 (7-8.6) 15 (7/70-8/71)	6.4 (6.4) 1 (7/1/74)	6.313 (6.3-6.4) 8 (7/1/74)	6.4 (6.4) 1 (7/1/74)	7.1 (6.1-8.1) 13 (8/74-2/75)	7 (6-8) 75 (8/74-2/75)	7.0 (6.4-8.1) 13 (8/74-2/75)
)-62) /70-8/71)	56.9 (51-62) 15 (7/70-8/71)	47 (47) 1 (7/1/74)	46.9 (46-48) 8 (7/1/74)	47 (47) 1 (7/1/74)	44.4 (25-54) 8 (8/70-2/75)	49.3 (36-55) 54 (8/74-2/75)	44.9 (31-54) 8 (8/74-2/75)
7 .2-3) /70-8/71)	2.6 (2.2-4.3) 15 (7/70-8/71)				3 (3) 1 (11/5/74)	2.7 (2.4-3.4) 8 (11/5/74)	2.6 (2.6) 1 (11/5/74)
.3 -83) /70-8/71)	67.6 (53-86) 15 (7/70-8/71)	61 (61) 1 (7/1/74)	61.8 (61-62) 8 (7/1/74)	62 (62) 1 (7/1/74)	57.8 (47-68) 4 (11/74-1/75)	58.6 (48-63) 23 (11/74-1/75)	55 (44-61) 3 (11/74-1/75)

FOLDOUT FRAME 3

370.0	370.7	385.8 R	388	391.6	396.8	407.7
17.1 (6.9-26.4) 96 (8/74-2/75)	18.9 (6.8-27) 17 (8/74-2/75)	24(8) (24) 1 (7/5/73)	15 (9.4-26.1) 38 (12/73-2/75)	14.4 (9.6-25.3) 9 (12/73-2/75)	15.2 (9.3-26) 32 (12/73-2/75)	14.2(9) (7.2-26) 5 (1/74-1/75)
9.5 (2.9-37) 46 (8/74-1/75)	9.9 (5.4-22) 7 (8/74-1/75)	10 (10) 1 (7/5/73)	12.3 (2.8-25) 17 (12/73-2/75)	14.2 (4.7-27) 6 (12/73-2/75)	12.3 (4.2-23) 10 (12/73-10/74)	19.6 (3.3-50) 5 (1/74-1/75)
166.7 (150-180) 33 (9/74-1/75)	173.3 (160-180) 6 (9/74-12/74)	180 (180) 1 (7/5/73)	157.5 (140-180) 16 (12/73-2/75)	162 (140-180) 5 (12/73-2/75)	159 (150-170) 10 (12/73-10/74)	148 (110-180) 5 (1/74-1/75)
8.7 (5.8-11.8) 92 (8/74-2/75)	8.2 (6.8-11.3) 14 (8/74-2/75)	0.1 (0.1) 1 (7/5/73)	9.4 (5.6-12) 33 (12/73-2/75)	9.56 (6.3-11.5) 8 (12/73-2/75)	9.2 (5.8-11.9) 24 (12/73-2/75)	
1.16 (1.0-1.7) 8 (11/5/74)	1.4 (1.4) 1 (11/5/74)	2.4 (2.4) 1 (7/5/73)	1.2 (1.0-2.3) 17 (12/73-2/75)	1.2 (1-1.5) 6 (12/73-2/75)	1.2 (1-1.5) 10 (12/73-10/74)	1.1 (1-1.4) 3 (1/74-7/74)
7.1 (2-39) 46 (8/74-1/75)	5.4 (9-3) 7 (8/74-1/75)	3 (3) 1 (7/5/73)	5.8 (2-9) 5 (12/73-10/74)		6 (1-9) 5 (12/73-10/74)	5.4 (3-7) 5 (1/74-1/75)
7 (6-8) 75 (8/74-2/75)	7.0 (6.4-8.1) 13 (8/74-2/75)	7.2 (7.2) 1 (7/5/73)	6.9 (6.1-7.4) 29 (12/73-2.75)	6.8 (6.3-7.1) 6 (12/73-2/75)	6.8 (6.3-7.5) 25 (12/73-2/75)	7.2 (6.7-7.7) 5 (1/74-1/75)
49.3 (36-55) 54 (8/74-2/75)	44.9 (31-54) 8 (8/74-2/75)	65 (65) 1 (7/5/73)	49.6 (44-56) 29 (12/73-2/75)	53.2 (48-61) 6 (12/73-2/75)	49.6 (44-55) 25 (12/73-2/75)	48.6 (41-56) 5 (1/74-1/75)
2.7 (2.4-3.4) 8 (11/5/74)	2.6 (2.6) 1 (11/5/74)	2.5 (2.5) 1 (7/5/73)	1.8 (1-2.5) 5 (12/73-10/74)		1.5 (0.9-2.3) 5 (12/73-10/74)	2.3 (1.9-3.4) 5 (1/74-1/75)
58.6 (48-63) 23 (11/74-1/75)	55 (44-61) 3 (11/74-1/75)	77 (77) 1 (7/5/73)	68 (62-76) 5 (12/73-10/74)		67.6 (62-72) 5 (12/73-10/74)	54.6 (46-61) 5 (1/74-1/75)

FOLDOUT FRAME 4

	PARAMETER	UNITS	277.98 (3)	281.67	283.94	288.78	291.76	293.7
11	Total Coliform	/100 ml			43.3 (10-180) 6 (7/73-10/74)			
12	Fecal Coliform	/100 ml			21.67 (10-80) 6 (7/73-10/74)			
13	Chloride	mg/ℓ		11.5 (4-45) 79 (4/70-4/73)	8.7 (3-25) 126 (4/70-1/75)		6 (4-8) 15 (7/73-1/75)	7 (6-8) 4 (10/73-1/7
14	Cyanide	mg/ℓ						
15	Nitrogen (organic)	mg/ℓ		0.22 (0.01-0.6) 79 (4/70-4/73)	0.23 (0.01-1) 126 (4/70-1/75)		0.17 (0.1-0.26) 15 (7/73-1/75)	0.19 (0.12-0.28 4 (10/73-1/7
16	Nitrogen (As NH_3)	mg/ℓ		0.068 (0.01-0.14) 79 (4/70-4/73)	0.07 (0.01-0.2) 126 (4/70-1/75)		0.065 (0.04-0.11 15 (7/73-1/75)	0.058 (0.02-0.1 4 (10/73-1/
17	Nitrogen (As Nitrate)	mg/ℓ		0.014 (0.01-0.04) 79 (4/70-4/73)	0.012 (0.03-0.01) 106 (4/70-4/74)		0.01 (0.01-0.01) 8 (7/73-4/74)	0.01 (0.01-0.0 4 (10/73-1/
18	Nitrogen (As Nitrate)	mg/ℓ		0.41 (0.07-0.96 79 (4/70-4/73)	0.41 (0.04-1.7) 106 (4/70-4/74)		0.39 (0.27-0.52) 8 (7/73-4/74)	0.42 (0.27-0.4 4 (10/73-1/
19	Phosphorous (Dissolved)	mg/ℓ		0.039 (0.01-0.11) 79 (4/70-4/73)	0.038 (0.006-0.2) 126 (4/70-1/75)		0.026 (0.01-0.04) 15 (7/73-1/75)	
20	Aluminum	µg/ℓ			1847 (200-8900) 47 (7/73-1/75)		1993 (300-5600) 15 (7/73-1/75)	

MAJOR WATER QUALITY PARAMETERS
(TENNESSEE RIVER BETWEEN WHEELER DAM AND W

RIVER MILES FROM OHIO R

93.7	293.88 (4)	295.87	301.06	306.0 L (5)	307.52	324.0 (6)	349.0 (7)	363.2
		10 (10-10) 2 (7/74-10/74)		54.3 (10-300) 7 (4/73-1/75)			40 (10-70) 2 (7/73-11/73)	84.4 (10-300) 9 (7/70-8/7
		10 (10-10) 2 (7/74-10/74)		18.6 (10-70) 7 (8/73-1/75)			10 (10-10) 2 (7/73-11/73)	11.1 (10-20) 9 (7/70-8/7
) 73-1/74)		5.9 (4-8) 22 (1/73-1/75)		6.1 (4-8) 7 (8/73-1/75)			6.4 (4-11) 17 (1/73-1/75)	18.3 (14-23) 15 (7/70-8/7
							0.01 (0.01-0.01) 2 (1/73-4/73)	
2-0.28) 73-1/74)		0.16 (0.05-0.38) 22 (1/73-1/75)		0.19 (0.07-0.29) 7 (8/73-1/75)		0.14 (0.14) 1 (9/14/72)	0.16 (0.08-0.49) 17 (1/73-1/75)	0.28 (0.15-0.5 15 (7/70-8/7
3 2-0.1) 73-1/74)		0.066 (0.03-0.12) 22 (1/73-1/75)		0.051 (0.03-0.12) 7 (8/73-1/75)		0.06 (0.06) 1 (9/14/72)	0.054 (0.02-0.15) 17 (1/73-1/75)	0.04 (0.01-0. 15 (7/70-8/7
1-0.01) 73-1/74)		0.013 (0.01-0.02) 14 (1/73-4/74)						0.01 (0.01-0. 15 (7/70-8/
7-0.49) 73-1/74)		0.5 (0.3-0.81) 14 (1/73-4/74)						0.35 (0.14-0. 15 (7/70-8/
		0.028 (0.01-0.06) 19 (1/73-1/75)		0.062 (0.03-0.21) 6 (8/73-1/75)			0.019 (0.01-0.03) 4 (1/73-11/73)	0.015 (0.003-0 15 (7/70-8/
		1504 (200-4500) 22 (1/73-1/75)		3543 (200-11000) 7 (8/73-1/75)			1012 (400-2700) 8 (1/73-12/74)	

FOLDOUT FRAME 2

RS (CONTINUED)[1]

D WIDOW'S CREEK POWER PLANT)

D RIVER

.2	365.0	368.3	368.6	369.0	369.4	370.0	370.7	385.
0) 3/71)	67.7 (10-360) 9 (7/70-8/71)				30 (30) 1 (11/5/74)	10 (10-10) 3 (11/5/74)	10 (10) 1 (11/5/74)	800 (800 1 (7/5
) 3/71)	12.2 (10-30) 9 (7/70-8/71)				10 (10) 1 (11/5/74)	10 (10-10) 3 (11/5/74)	10 (10) 1 (11/5/74)	10 (10) 1 (7/5
) 8/71)	18.6 (13-23) 15 (7/70-8/71)	5 (5) 1 (7/1/74)	5.1 (4-6) 8 (7/1/74)	6 (6) 1 (7/1/74)	7 (6-8) 3 (8/74-9/74)	7.2 (6-9) 23 (8/74-9/74)	6.8 (6-9) 4 (8/74-9/74)	6 (6) 1 (7/5
0.59) 8/71)	0.29 (0.15-0.85) 15 (7/70-8/71)	0.14 (0.14) 1 (7/1/74)	0.10 (0.07-0.16) 8 (7/1/74)	0.13 (0.13) 1 (7/1/74)	0.13 (0.1-0.16) 7 (8/74-1/75)	0.15 (0.03-0.43) 46 (8/74-1/75)	0.14 (0.07-0.2) 7 (8/70-2/75)	0.42 (0.4 1 (7/5
0.09) 8/71)	0.048 (0.01-0.1) 15 (7/70-8/71)	0.01 (0.01) 1 (7/1/74)	0.031 (0.01-0.07) 8 (7/1/74)	0.01 (0.01) 1 (7/1/74)	0.05 (0.01-0.1) 7 (8/74-1/75)	0.054 (0.01-0.17) 46 (8/74-1/75)	0.053 (0.01-0.17) 7 (8/74-1/75)	0.4 (0.4 1 (7/5
0.01) 8/71)	0.01 (0.01-0.01) 15 (7/70-8/71)							
0.47) 8/71)	0.31 (0.2-0.5) 15 (7/70-8/71)							
-0.026) 8/71)	0.013 (0.003-0.03) 15 (7/70-8/71)				0.02 (0.01-0.03) 2 (8/74-9/74)	0.02 (0.01-0.09) 15 (8/74-9/74)	0.01 (0.01-0.01) 2 (8/74-9/74)	
					500 (500) 1 (11/5/74)	425 (300-600) 8 (11/5/74)	400 (400) 1 (11/5/74)	1000 (100 1 (7/5

	370.0	370.7	385.8 R	388	391.6	396.8	407.7
4)	10 (10-10) 3 (11/5/74)	10 (10) 1 (11/5/74)	800 (8000) 1 (7/5/73)	73.6 (10-450) 11 (12/73-2/75)	326.7 (10-980) 6 (12/73-2/75)	246 (10-580) 5 (12/73-10/74)	
)	10 (10-10) 3 (11/5/74)	10 (10) 1 (11/5/74)	10 (10) 1 (7/5/74)	40 (10-320) 11 (12/73-2/75	66.7 (10-240) 6 (12/73-2/75)	34 (10-120) 5 (12/73-10/74)	
74)	7.2 (6-9) 23 (8/74-9/74)	6.8 (6-9) 4 (8/74-9/74)	6 (6) 1 (7/5/73)	6 (4-8) 5 (12/73-10/74)		6 (4-8) 5 (12/73-10/74)	5.6 (4-8) 5 (1/74-1/75)
6) 75)	0.15 (0.03-0.43) 46 (8/74-1/75)	0.14 (0.07-0.2) 7 (8/70-2/75)	0.42 (0.42) 1 (7/5/73)	0.14 (0.03-0.25) 17 (12/73-2/75)	0.13 (0.05-0.18) 6 (12/73-2/75)	0.18 (0.09-0.38) 10 (12/73-10/74)	0.13 (0.11-0.15) 5 (1/74-1/75)
1) 75)	0.054 (0.01-0.17) 46 (8/74-1/75)	0.053 (0.01-0.17) 7 (8/74-1/75)	0.4 (0.4) 1 (7/5/73)	0.086 (0.02-0.3) 17 (12/73-2/75)	0.055 (0.01-0.15) 6 (12/73-2/75)	0.06 (0.05-0.07) 10 (12/73-10/74)	0.058 (0.04-0.08) 5 (1/74-1/75)
03) 74)	0.02 (0.01-0.09) 15 (8/74-9/74)	0.01 (0.01-0.01) 2 (8/74-9/74)		0.038 (0.01-0.08) 5 (12/73-10/74)		0.025 (0.01-0.046) 5 (12/73-10/74)	
	425 (300-600) 8 (11/5/74)	400 (400) 1 (11/5/74)	1000 (1000) 1 (7/5/73)	1340 (500-2500) 5 (12/73-10/74)		1300 (300-2400) 5 (12/73-10/74)	

	PARAMETER	UNITS	277.98 [3]	281.67	283.94	288.78	291.76
21	Chromium	µg/ℓ	27.8 (5-50) 16 (1/70-4/73)		10.3 (5-50) 62 (1/70-1/75)	31.3 (5-50) 14 (1/70-4/73)	17.4 (5-50) 30 (1/70-1/75)
22	Copper	µg/ℓ	28.1 (10-130) 16 (1/70-4/73)		35 (10-230) 62 (1/70-1/75)	24.3 (10-130) 14 (1/70-4/73)	21 (10-60) 30 (1/70-1/75)
23	Iron (Total)	µg/ℓ	442 (50-1700) 16 (1/70-4/73)	536 (50-2100) 79 (4/70-4/73)	654 (50-3300) 129 (1/70-1/75)	450 (150-1000) 14 (1/70-4/73)	741 (130-2600) 30 (1/70-1/75)
24	Iron (Dissolved)	µg/ℓ	50 (50) 1 (6/7/72)	140 (50-650) 79 (4/70-4/73)	112 (50-720) 126 (4/70-1/75)		87 (50-160) 15 (7/73-1/75)
25	Iron (Ferrous)	µg/ℓ		71 (20-180) 78 (4/70-4/73)	85 (10-300) 125 (4/70-1/75)		109 (20-210) 15 (7/73-1/75)
26	Manganese	µg/ℓ	78.5 (40-120) 7 (1/70-1/73)	71.0 (10-290) 79 (4/70-4/73)	76.8 (20-730) 127 (1/70-1/75)	61.7 (30-100) 6 (1/70-1/73)	65.7 (20-160) 21 (1/70-1/75)
27	Mercury	µg/ℓ			0.55 (0.2-12) 47 (7/73-1/75)		0.35 (0.2-1.6) 15 (7/73-1/75)
28	Nickel	µg/ℓ	50 (50-50) 16 (1/70-4/73)		71 (50-430) 62 (1/70-1/75)	50 (50-50) 14 (1/70-4/73)	54 (50-160) 30 (1/70-1/75)
29	Zinc	µg/ℓ	30.6 (10-90) 16 (1/70-4/73)		28.5 (10-120) 62 (1/70-1/75)	272.9 (10-3300) 14 (1/70-4/73)	24.8 (10-60) 29 (1/70-1/75)

FOLDOUT FRAME /

MAJOR WATER QUALITY PARAMETERS
(TENNESSEE RIVER BETWEEN WHEELER DAM AND W

RIVER MILES FROM OHIO

293.7	293.88 (4)	295.87	301.06	306.0 L (5)	307.52	324.0 (6)	349.0 (7)
27.9 (5-50) 16 (1/70-4/73)		15.4 (5-50) 35 (1/70-1/75)	28.1 (5-50) 16 (1/70-4/73)	5.4 (5-8) 7 (8/73-1/75)	28.4 (5-60) 16 (1/70-4/73)		5 (5-5) 8 (1/73-12/74)
28.1 (10-210) 16 (1/70 4/73)		24.9 (10-200) 35 (1/70-1/75)	16.3 (10-40) 16 (1/70-4/73)	160 (20-640) 7 (8/73-1/75)	21.2 (10-120) 16 (1/70-4/73)		13.8 (10-30) 8 (1/73-12/74)
537 (90-960) 16 (1/70-4/73)		621 (110-2600) 35 (1/70-1/75)	436 (140-770) 16 (1/70-4/73)	2017 (230-6300) 7 (8/73-1/75)	499 (150-1700) 16 (1/70-4/73)		600 (150-1700) 17 (1/73-1/75)
		109 (50-410) 19 (1/73-1/75)		67 (50-120) 7 (8/73-1/75)			85 (50-130) 4 (1/73-11/73)
		90 (10-180) 22 (1/73-1/75)		107 (70-190) 7 (8/73-1/75)			97 (50-170) 3 (1/73-11/73)
95 (40-220) 6 (1/70-1/73)		64.8 (30-160) 27 (1/70-1/75)	76 (60-80) 5 (1/70-1/71)	255.7 (40-800) 7 (8/73-1/75)	90 (60-130) 4 (4/70-1/71)		400 (30-5900) 17 (1/73-1/75)
		0.72 (0.2-7.4) 22 (1/73-1/75)		0.2 (0.2-0.2) 7 (8/73-1/75)			2.2 (0.2-9) 8 (1/73-12/74)
50 (50-50) 16 (1/70-4/73)		56 (50-210) 35 (1/70-1/75)	50 (50-50) 16 (1/70-4/73)	70 (50-180) 7 (8/73-1/75)	50 (50-50) 16 (1/70-4/73)		50 (50-50) 8 (1/73-12/74)
250.7 (10-3400) 15 (1/70-4/73)		28.5 (10-100) 34 (1/70-1/75)	32.7 (10-110) 15 (1/70-4/73)	42.9 (10-90) 7 (8/73-1/75)	56.7 (10-290) 15 (1/71-4/73)		28.7 (10-90) 8 (1/73-12/74)

S (CONTINUED)[1]
D WIDOW'S CREEK POWER PLANT)

O RIVER

)	363.2	365.0	368.3	368.6	369.0	369.4	370.0	370.7
						5 (5) 1 (11/5/74)	5 (5-5) 8 (11/5/74)	5 (5) 1 (11/5/74)
						10 (10) 1 (11/5/74)	15 (10-40) 8 (11/5/74)	50 (50) 1 (11/5/74)
	249 (50-560) 15 (7/70-8/71)	260 (80-560) 15 (7/70-8/71)	180 (180) 1 (7/1/74)	455 (130-1900) 8 (7/1/74)	150 (150) 1 (7/1/74)	450 (450) 1 (11/5/74)	334 (260-540) 8 (11/5/74)	440 (440) 1 (11/5/74)
	87 (50-230) 15 (7/70-8/71)	62 (50-100) 13 (7/70-8/71)				60 (60) 1 (11/5/74)	64 (50-90) 8 (11/5/74)	50 (50) 1 (11/5/74)
	50 (50-50) 15 (7/70-8/71)	50 (50-50) 15 (7/70-8/71)						
	75.3 (10-180) 15 (7/70-8/71)	102.6 (20-500) 15 (7/70-8/71)	20 (20) 1 (7/1/74)	76.3 (20-370) 8 (7/1/74)		40 (40) 1 (11/5/74)	50 (30-70) 8 (11/5/74)	70 (70) 1 (11/5/74)
						50 (50) 1 (11/5/74)	118 (50-490) 8 (11/5/74)	140 (140) 1 (11/5/74)
						10 (10) 1 (11/5/74)	10 (10-10) 8 (11/5/74)	10 (10) 1 (11/5/74)

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4	370.0	370.7	385.8 R	388	391.6	396.8	407.7
74)	5 (5-5) 8 (11/5/74)	5 (5) 1 (11/5/74)	5 (5) 1 (7/5/73)	5 (5-5) 5 (12/73-10/74)		5 (5-5) 5 (12/73-10/74)	10.6 (5-21) 5 (1/74-1/75)
74)	15 (10-40) 8 (11/5/74)	50 (50) 1 (11/5/74)	280 (280) 1 (7/5/73)	62 (10-130) 5 (12/73-10/74)		22 (10-50) 5 (12/73-10/74)	62 (10-140) 5 (1/74-1/75)
74)	334 (260-540) 8 (11/5/74)	440 (440) 1 (11/5/74)	1200 (1200) 1 (7/5/73)	644 (310-1300) 5 (12/73-10/74)		702 (250-1400) 5 (12/73-10/74)	1206 (280-2400) 5 (1/74-1/75)
74)	64 (50-90) 8 (11/5/74)	50 (50) 1 (11/5/74)	50 (50) 1 (7/5/73)	84 (50-160) 5 (12/73-10/74)		80 (50-110) 5 (12/73-10/74)	
			240 (240) 1 (7/5/73)	136 (70-280) 5 (12/73-10/74)		106 (40-230) 5 (12/73-10/74)	
4)	50 (30-70) 8 (11/5/74)	70 (70) 1 (11/5/74)	930 (930) 1 (7/5/73)	44 (30-60) 5 (12/73-10/74)		50 (20-60) 5 (12/73-10/74)	70 (30-120) 5 (1/74-1/75)
			5.3 (5.3) 1 (7/5/73)	0.44 (0.2-1.1) 5 (12/73-10/74)		0.98 (0.2-4.1) 5 (12/73-10/74)	
4)	118 (50-490) 8 (11/5/74)	140 (140) 1 (11/5/74)	50 (50) 1 (7/5/73)	108 (50-340) 5 (12/73-10/74)		50 (50-50) 5 (12/73-10/74)	50 (50-50) 5 (1/74-1/75)
4)	10 (10-10) 8 (11/5/74)	10 (10) 1 (11/5/74)	250 (250) 1 (7/5/73)	68 (10-220) 5 (12/73-10/74)		18 (10-20) 5 (12/73-10/74)	60 (40-80) 5 (1/74-1/75)

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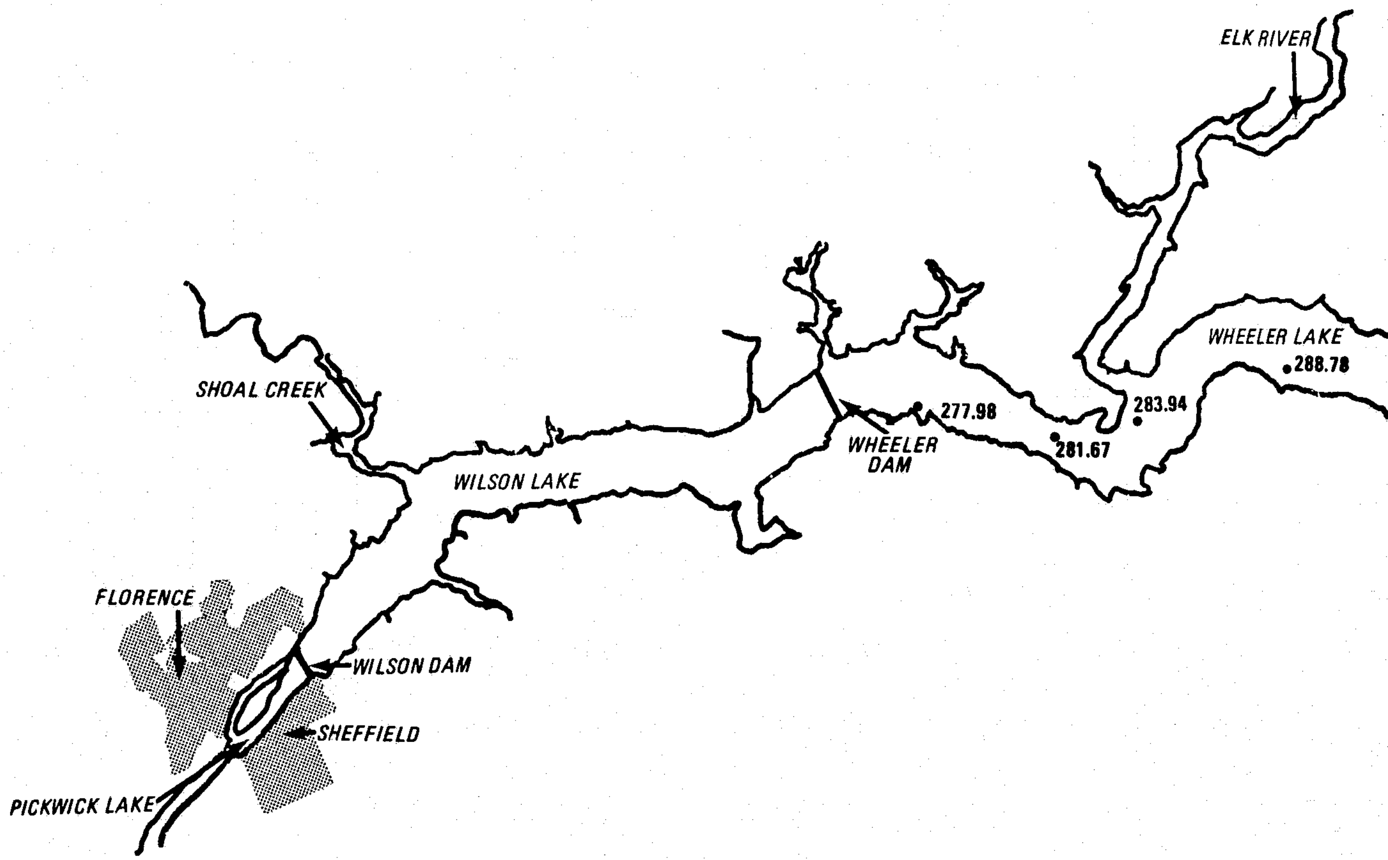
ELK RIVER
WHEELER LAKE
288.78
283.94
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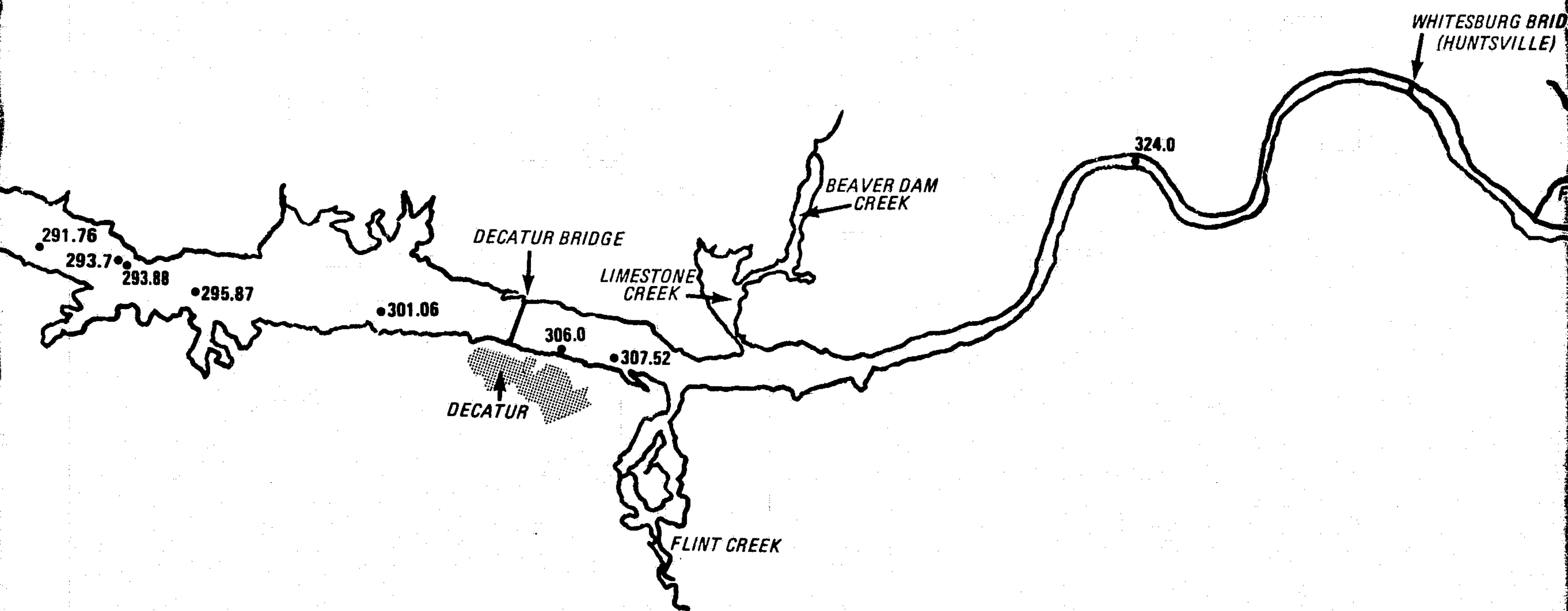
WHEELER DAM
SHOAL CREEK
WILSON LAKE
FLORENCE
WILSON DAM
SHEFFIELD
PICKWICK LAKE



RIVER MILE LOCATIONS REFER

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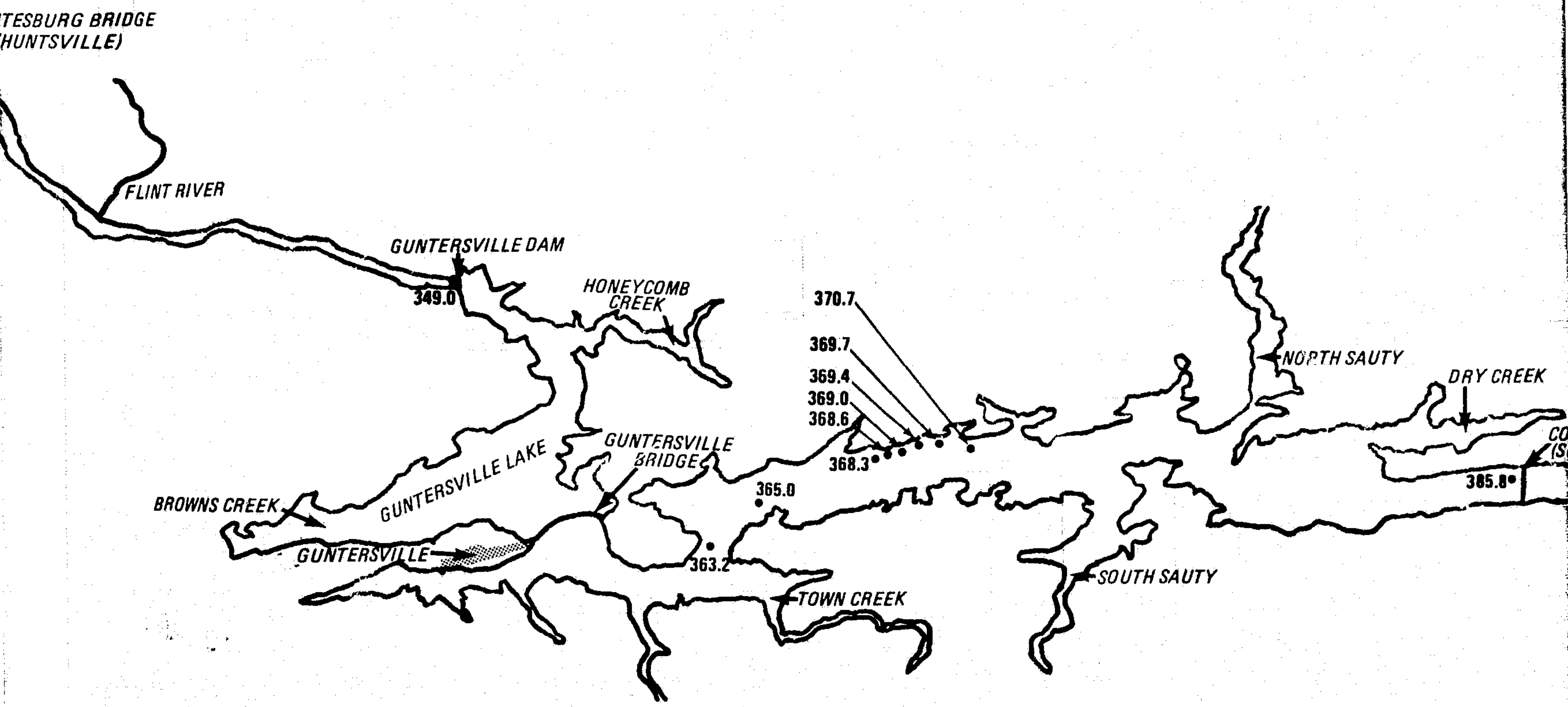

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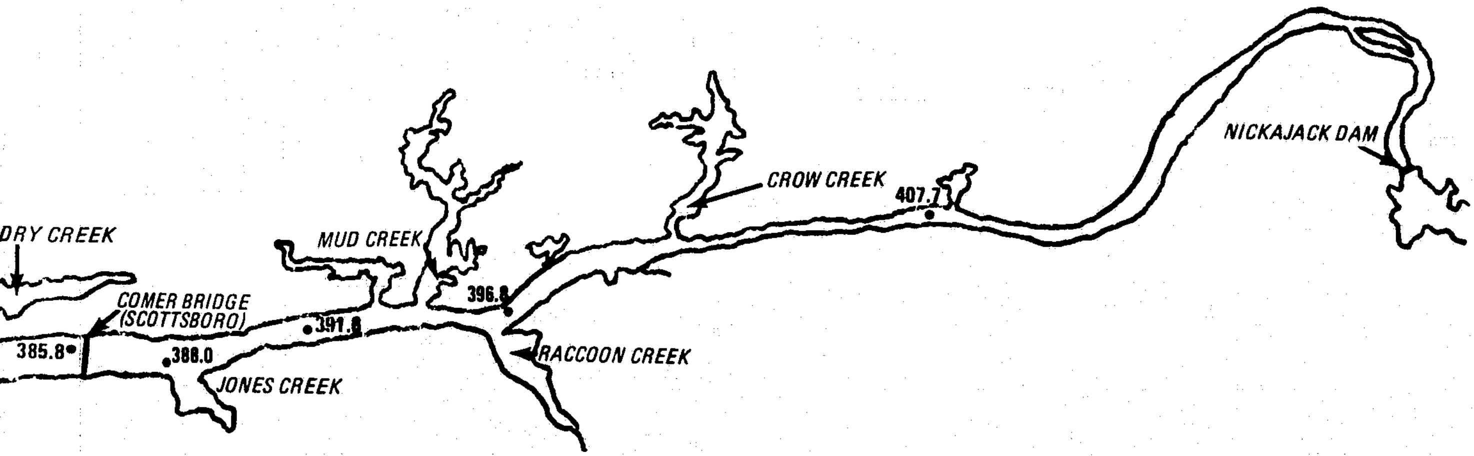

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FOOTNOTES TO TABLE II

MAJOR WATER QUALITY PARAMETERS

(1) From STORET data bank

(2) First line denotes average of all data. Second line denotes data range. Third line denotes total number of data. Fourth line denotes period of sampling.

(3) 3 miles east of Wheeler Dam

(4) Brown's Ferry Power Plant

(5) 1 mile east of Decatur Bridge

(6) 3 miles east of Triana

(7) Guntersville Dam

(8) Scottsboro Bridge

(9) Widow's Creek Power Plant

Table III. Tennessee River Water Quality Parameters Included in STORET Data Bank

PARAMETER				PARAMETER			
00002	HSAMPLOC	% FROM	RT BANK	00335	COD	LOWLEVEL	MG/L
00003	VSAMPLOC	DEPTH	FEET	00350	BOD	14 DAY	MG/L
00008	LAB	IDENT.	NUMBER	00400	PH		SU
00010	WATER	TEMP	CENT	00410	T ALK	CACO3	MG/L
00061	STREAM	FLOW,	INST-CFS	00415	PHEN-PH-	LFIN ALK	MG/L
00070	TURB	JKSN	JTU	00500	RESIDUE	TOTAL	MG/L
00080	COLOR	PT-CO	UNITS	00515	RESIDUE	DISS-105	MG/L
00081	AP COLOR	PT-CO	UNITS	00530	RESIDUE	TOT NFLT	MG/L
00085	ODOR	THRSH NO	RM. TEMP	00605	ORG N	N	MG/L
00095	CNDUCTVY	AT 25C	MICROMHO	00610	NH3-N	TOTAL	MG/L
00300	DO		MG/L	00615	NO2-N	TOTAL	MG/L
00303	BOD	1 DAY	MG/L	00620	NO3-N	TOTAL	MG/L
00304	BOD	2 DAY	MG/L	00630	NO2&NO3	N-TOTAL	MG/L
00305	BOD	3 DAY	MG/L	00650	T PO4	PO4	MG/L
00306	BOD	4 DAY	MG/L	00653	SOLPO4-T	PO4	MG/L
00310	BOD	5 DAY	MG/L	00665	PHOS-TOT		MG/L P
00312	BOD	6 DAY	MG/L	00666	PHOS-DIS		MG/L P
00315	BOD	7 DAY	MG/L	00671	PHOS-DIS	ORTHO	MG/L P
00316	BOD	8 DAY	MG/L	00680	T ORG C	C	MG/L
00317	BOD	9 DAY	MG/L	00685	T. INORG	C	MG/L
00322	BOD	10 DAY	MG/L	00690	T-CARBON	C	MG/L
00323	BOD	15 DAY	MG/L	00722	CYANIDE	FREE CN	MG/L
00326	BOD	28 DAY	MG/L	00900	TOT HARD	CACO3	MG/L

PARAMETER				PARAMETER			
00916	CALCIUM	CA-TOT	MG/L	01055	MANGNESE	MN	µG/L
00927	MGNSIUM	MG,TOT	MG/L	01056	MANGNESE	MN,DISS	µG/L
00929	SODIUM	NA,TOT	MG/L	01067	NICKEL	NI,TOTAL	µG/L
00937	PTSSIUM	K,TOT	MG/L	01077	SILVER	AG,TOT	µG/L
00940	CHLORIDE	CL	MG/L	01082	STRONTUM	SR,TOT	µG/L
00945	SULFATE	SO4-TOT	MG/L	01092	ZINC	ZN,TOT	µG/L
00951	FLOURIDE	F,TOTAL	MG/L	01105	ALUMINUM	AL,TOT	µG/L
00956	SILICA	TOTAL	MG/L	01132	LITHIUM	LI,TOT	µG/L
01002	ARSENIC	AS,TOT	µG/L	01147	SELENIUM	SE,TOT	µG/L
01007	BARIUM	BA,TOT	µG/L	01152	TITANIUM	TI,TOT	µG/L
01012	BERYLIUM	BE,TOT	µG/L	31501	TOT COLI	MFIMENDO	/100ML
01022	BORON	B,TOT	µG/L	31503	TOT COLI	MFDLENDO	/100ML
01027	CADMIUM	CD,TOT	µG/L	31505	TOT COLI	MPN CONF	/100ML
01034	CHROMIUM	CR,TOT	µG/L	31616	FEC COLI	MFM-FCBR	/100ML
01037	COBALT	CO,TOTAL	µG/L	32730	PHENOLS	TOTAL	µG/L
01042	COPPER	CU,TOT	µG/L	70001	X SEC.	COMPOSIT	LOCATION
01045	IRON	FE,TOT	µG/L	70300	RESIDUE	DISS-180	C MG/L
01046	IRON	FE,DISS	µG/L	71865	IODIDE	I	MG/L
01047	FERROUS	IRON	µG/L	71900	MERCURY	HG,TOTAL	µG/L
01051	LEAD	PB,TOT	µG/L	80111	NITROGEN	DRY WGT	MG/KG

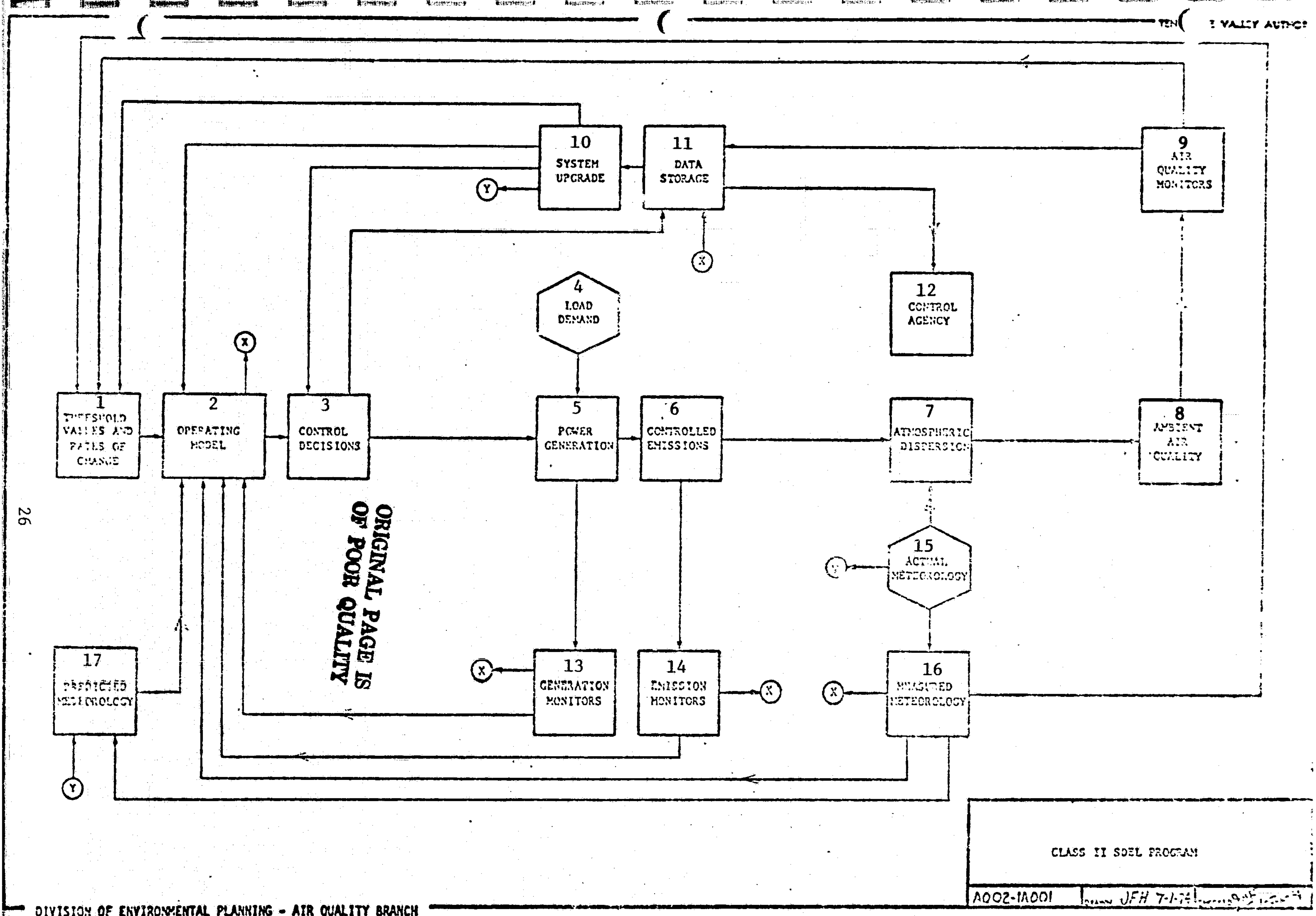

Figure 1: ELEMENTS OF THE SO_2 EMISSION LIMITATION PROGRAM - KINGSTON STEAM PLANT

APPENDIX A

ABSTRACTS OF SELECTED ARTICLES AND REPORTS

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Appendix A: Abstracts of Selected Articles and Reports

1. Simulation of Water Quality in Streams & Canals-Program Documentatation and Users Manual, Texas Water Development Board, Austin, Texas (September 1970).

This program simulates the spatial and temporal variations in biochemical oxygen demand (B.O.D.) and dissolved oxygen (D.O.) under various conditions of temperature and headwater flow. If desired, the minimum dissolved oxygen concentration in the stream system may be compared against a prespecified dissolved oxygen concentration target level. If the minimum dissolved oxygen concentration is below the target level, the program will compute the required amount of flow augmentation to bring the dissolved oxygen concentration up to the target level in the entire system. This program is designed to be run for varying climate and hydraulic conditions during a twelve month period. The major restriction of the program is that large impoundments such as reservoirs cannot be considered.

2. Simulation of Water Quality in Streams and Canals - Theory and Description of the QUAL-I Mathematical Modeling System, Report 128, Texas Water Development Board, Austin, Texas (May 1971).

The set of interrelated quality routing models (QUAL-I) described in the report is useful for the prediction of the temporal and spatial distribution of temperature, biochemical oxygen demand, dissolved oxygen, and conserved minerals within a segment of a river basin. The governing differential equation is solved by an implicit-finite-difference technique under the assumption that advection (the rate of change of concentration at a

reference point due to fluid motion) along the primary axis of flow is the primary mode of transport.

Comparison of the prediction of this modeling system and field data from a segment of a river basin containing multiple headwater sources, waste loading, and branching streams produced good agreement between predicted and observed quality profiles.

3. Weil, J. and Fischer, H. B., Effect of Stream Turbulence on Heater Water Plumes, Journal of the Hydraulics Division, ASCE, vol. 100, No. HY7, pp. 951-970, (July 1974).

This study is intended to provide information on mixing of a heated water jet in turbulent flow, hopefully to improve the design engineer's ability to predict thermal patterns near proposed new power plants.

The study is concerned with the interaction of the buoyancy and receiving water turbulence. Heated water is introduced through a semi-circular nozzle into channel flow at the surface center line. The jet velocity is parallel and equal to the local ambient velocity. Thus the jet has no excess momentum, and lateral dispersion is due to buoyant motion and turbulence. The origin of the coordinate system is at the water surface at the point of injection. The x, y, and z axes define the downstream, lateral and depth directions. Temperature distributions are measured in the jet field downstream from the source. Ambient mixing is significant but jet mixing is not.

4. Bush, R. M., et al, Potential Effects of Thermal Discharge on Aquatic Systems, Environmental Science & Technology, vol. 8, no. 6, pp. 561-568, (June 1974).

Ecological changes in the aquatic environment caused by temperature increases are estimated in order to aid the decision process in siting cooling water discharges. Principal consideration is given to the fish community for which predictions of change in composition are based on lethal and preferred temperatures. Six representative river systems are considered. Insufficient data precluded similar community response estimations for fresh water invertebrates. However, data indicate that adequate protection of fish species results in like protection of the invertebrate, fauna, and thus the estimated effect of elevated temperatures on fresh water fish communities should suffice as a guideline for both the protection of fish and invertebrates. Similar predictions were not possible for the marine community, since thermal requirements are known for only a few species. However, existing data and site studies are summarized for use as guidelines.

5. Waste Source and Water Quality Studies-Mobile River and Tributaries, Mobile, Alabama, EPA Athens, Georgia (February 1974).

EPA conducted waste source and water quality investigations of the Mobile River, Alabama, during 1973. The studies were limited to Mobile River and tributaries between Mobile Bay and the confluence of the Spanish River. Primary study objectives were:

(a) To determine the feasibility of upgrading current lower water use classification of the Mobile River, Chickasaw Creek, and Threemile Creek to the Fish and Wildlife use classification

(b) To generate industrial waste source data in order to permit evaluation of National Pollutant Discharge Elimination System permits, and

(c) To conduct treatment efficiency studies at selected municipal waste treatment plants designated by the EPA.

6. Weber, J. E., et al., On the Mismatch Between Data and Models of Hydrologic and Water Resource Systems, Water Resources Bulletin AWRA, vol. 9, no. 6, pp. 1075-1088, (December 1973).

Many difficulties exist in matching mathematical models with data. This paper identifies elements of this problem and discusses considerations involved in model evaluation. The well known multivariate linear regression model is selected to illustrate the distinction between accuracy and precision and between estimation and prediction (because this model is commonly misused). No amount of additional data will improve the accuracy of a poor model. A high value of R^2 (where R^2 is the ratio of Regression Sum of Squares to Total Sum of Squares) while indicative of a good matching between the observed data and model estimates, is a poor criterion for judging adequacy of the model for making good predictions of future events. Model evaluation also includes the problem of introducing secondary data and proxy variables (one-dimensional parameters used to represent a multi-criteria environment, such as environmental quality, purity of water, etc.) into a model. Secondary data frequently enter, for example, the mass, energy and water conservation equations because of the difficulties in measuring the primary variables. Proxy variables arise because of a desire to collapse a vector of incomparable values, say, of water quality into a single number. Review of the above issues indicates that model evaluation is a multi-criterion problem, often imbedded within a large framework where models are intended to meet multiple objectives. The mismatch of models and data has increasing legal and social consequences.

7. Hwang, C. L., et al., Regional Water Quality Management by the Generalized Reduced Gradient Method, Water Resources Bulletin AWRA, vol. 9, no. 6, pp. 1159-1181, (December 1973).

A river basin-wide water quality management system is considered. The river receives thermal as well as organic wastes. At-source treatment of these pollutants is imposed to control the basin-wide water quality. The related water quality standards are: minimum DO concentration, maximum allowable BOD concentration, maximum allowable stream temperature, and allowable rise in stream temperature. The general dynamic mathematical model representing water quality in streams and the thermal effects on BOD and DO concentration is presented. This model is highly nonlinear in nature. The optimal management problem involving the model is solved by a recently developed nonlinear programming technique - the generalized reduced gradient (GRG) method. Comparison of results obtained by the GRG method with results based on dynamic programming and also with results using a more realistic mathematical model and a simple model respectively are represented. The GRG method can be applied to the design of new water quality management programs as well as to the examination of existing programs. It can also be applied to the study of the influence of alternate policies and constraints.

8. Moore, S. F., Estimation Theory Applications to Design of Water Quality Monitoring Systems, Journal of the Hydraulics Division, ASCE, Vol. 99, No. HY5, pp. 815-831, (May 1973).

The objectives of this research were to apply filter theory, a technique used extensively in aerospace navigation and guidance problems, to the design and improvement of monitoring programs for aquatic ecosystems.

Monitoring systems are characterized by the variables to be sampled and the temporal and spatial frequency of sampling. A "best" monitoring program is selected from a feasible set of monitoring programs by sequentially minimizing the rate of cost expenditure subject to constraints on the uncertainty in the estimates of the state of the system. Because the objectives of this research were primarily methodological, data from a real system are not utilized. The results reported are based on data generated from a stochastic simulation model.

9. Morgan, J. M., et. al., Application of Stream Water Quality Models to Alabama, Draft Report, Contract No. WRP73-1, Auburn University, Auburn, Alabama (June 1973).

The objective of this report was to apply several existing water quality models to an actual river basin in Alabama. Two stream water quality models were applied to the Sougahatchee Creek basin near Auburn, Alabama, namely:

a) STREM, a model developed for the Delaware River Basin Commission by Hydroscience, Inc., Westwood, New Jersey.
b) DOSAG, a model developed by the Systems Engineering Division of the Texas Water Development Board.

10. Pingry, D. E., and Whinston, A. W., Multigoal Water Quality Planning Model, Journal of the Environmental Engineering Division, ASCE, Vol. 99, No EEG, pp. 909-922, (Dec. 1973).

This paper directs itself to the objective of determining the most economical way of achieving water quality goals on a regional or basin wide basis rather than simply applying current regulations which impose

uniform discharge limitations and treatment plant requirements regardless of the effect upon over-all water quality goals.

11. Dracup, J. A. and Fogarty, T. J., Optimal Planning for a Thermal Discharge Treatment System, Water Resources Research, Vol. 10, No. 1, pp. 67-71, (February 1974).

The objective of this study was to minimize the cost of treating water which has been thermally polluted by a series of nuclear power plants located adjacent to a river. The procedure used to solve this problem consists of implementation of two mathematical models; the first model determines the effects of a discharge upon the river temperature and the second model determines the minimum cost of treating the heated discharge, considering bypass piping, cooling towers, and cooling ponds as alternative modes of treatment. Bypass piping systems are shown to have cost advantages.

12. Bolus, R. L. et al., The Design of a Thermal Monitoring System, MTS Journal, Vol. 7, no. 7, pp. 36-40, (October 1973).

A mobile electronic monitoring and automatic recording data system for the waste heat study around the nuclear power plant at Surry, Virginia, has been designed to measure several different environmental parameters on the James River at the Hog Island site. The data are multiplexed, digitized, coded, and then recorded on magnetic tape in computer compatible format. Computer drawn plots and graphs of these data provide a background for the waste heat study, indicating the state of the environment before the power plant becomes operational.

13. Ferguson, W. C., et al., Water Quality Monitoring at the Site of a Proposed Base Metal Mining Complex, CIM Bulletin, pp. 161-166, (March 1973).

The objective of this study was to establish base-line water quality characteristics. Full realization of the responsiblity of minimizing the effects of any proposed activity or activities upon the environment calls for the establishment of a program by which any change in water quality will be detected before detrimental conditions ensue, permitting prompt corrective measures to be taken.

In the reported study, the waters were sampled and analyzed four to five times per year. On-site measurements and analyses were made of flow, dissolved oxygen, temperature, and pH. Additional samples also were collected and analyzed for a wide range of chemical and biological characteristics.

14. Milanov, T., Cooling Problems in Thermally-Polluted Recipients, Nordic Hydrology 4, pp. 237-255, (1973).

The extension of heated water plumes from Swedish power plants into receiving waters was studied using a meteorological approach. Actual air-water surface areas of the dispersed plumes were determined and compared with areas calculated on the assumption that heat transfer from the surface of the heated water to the atmosphere predominates and that heat transfer to the colder receiving waters is negligible. The comparison shows that this is not the case, but rather that the latter equals or exceeds the former.

15. Jensen, A. L., Statistical Analysis of Biological Data from Preoperational - Postoperational Industrial Water Quality Monitoring, Water Research, Pergamon Press, Vol. 7, pp. 1331 - 1347, (1973).

An application of methods for the analysis of biological data from preoperational - postoperational industrial surveys is presented. Repeated observations at the same sampling station form a time series in which the observations are not statistically independent, and the usual forms of statistical analysis do not apply. If the data do not indicate a trend, easy-to-use control charts can be applied to analyze this form of data. A careful analysis of biological monitoring data requires a well-designed sampling scheme and removal of seasonal fluctuations from the data. It is shown that without collecting and analyzing an unreasonable number of samples, stream monitoring can detect only relatively large changes in aquatic populations (e.g., changes equal or greater than 25-30 per cent for the most common fauna populations).

APPENDIX B

ARTICLES AND REPORTS REVIEWED BUT NOT ABSTRACTED

Appendix B: Articles and Reports Reviewed But Not Abstracted

1. Study of Water Quality Prediction Models for Use in Alabama, Alabama Development Office, Report no. ALA-AU-X996-WRC-72-6, Montgomery, Alabama (February 1973).

2. LeRoy, V. W. and Lincoln, A. J., Spectrochemical Method for the Determination of 36 Elements in Industrial Effluent, Analytical Chemistry, vol. 46, no. 3, pp. 369-373 (March 1974).

3. Egan, W. C., Boundaries of ERTS and Aircraft Data Within Which Useful Water Quality Information Can Be Obtained, Research Department, Grumman Aerospace Corporation, Bethpage, New York (1974).

4. Leh, F. and Chan, K. W., Instruments and Methods for Determining Trace Metals, Chemtech, pp. 178-182 (March 1974).

5. Afghan, B. K. and Sekerka, I., Recent Improvements in Analytical Methodology for Water Pollution Control, Chemistry in Canada, pp. 21-23, (April 1974).

6. Harrison, C. H., Comprehensive Planning for Water and Related Land Resources in Alabama, contract no. WRP71-1, Auburn University, Auburn, Alabama (February 1972).

7. Muspratt, M. A., Quality Control Applied to River Pollution, Intern. J. Environmental Studies, vol. 5, pp. 137-142 (1973).

8. Blakeley, C. P. and Thomas, T. K., Instrumentation for Water Pollution Monitoring, Environmental Science & Technology, pp. 1006-1010.

9. Bayer, M. B., Nonlinear Programming in River Basin Modeling, Water Resources Bulletin AWRA, vol. 10, no. 2, pp. 311-317 (April 1974).

10. Ward, R. C. et al., Surveillance in Water Quality Management, Journal WPCF, vol. 45, no. 10, pp. 2081-2087 (October 1973).

11. Ortolano, L. et al., Cost of Thermal Effluent Standards for Power Plants, Journal of the Power Division, pp. 15-31, (July 1974).

12. Tremor, J. W., Potential NASA Initiative in Water Resources, Earth Science Application Office, AMES Research Center, (January 12, 1973).

13. Gilligan, R. M., Forecasting the Effects of Polluting Discharges on Estuaries Part I, II, and III, Chemistry and Industry, pp. 865-874, 909-916, 950-958, (Nov. 1972 and December 1972).

14. Novotny, V. and Knenkel, P. A., Simplified Mathematical Model of Temperature Changes in Rivers, Journal WPCF, Vol. 45, no. 2, pp. 240-248, (February 1973).

15. Carlton, T. L. et al., Nature and Analysis of Chemical Species, Journal WPCF, Vol. 46, No. 6, pp. 1031-1035, (June 1974).

16. Dean, J. G. et al., Pending Water Pollution Legislation Requires Heavy Metal Removal Not Only Before Industrial Wastes are Discharged into Navigable Waters, but also Prior to Ocean or Land Disposal, Environmental Science and Technology, Vol. 6, pp. 519-522 (June 1972).

17. Mahloch, J. L., Graphical Interpretation of Water Quality Data, Water, Air, and Soil Pollution 3, pp. 217-236, (1974).

18. Perks, A., Computer Analysis of Water Systems Saves Time, Money, Water and Pollution Control, p. 20, (April 1974).

19. Van Loon, J. C., The Emerging Role of Selective Ion Electrodes, Water and Pollution Control, pp. 23-25, (Oct. 1973).

20. Folkert, M. B. and Woodle, R. V., Status of Environmental Sensing Systems for Unattended Ocean Buoys, MTS Journal, Vol. 8, no. 4, pp. 29-35, (April-May 1974).

21. Shriver, L. E. and Young, J. C., Oxygen Demand Index as a Rapid Estimate of Biochemical Oxygen Demand, Journal WPCF, Vol. 44, no. 11, pp. 2140-2147, (Nov. 1972).

22. Winn, C. B., The Use of Hydrological Simulation and Remote Sensing in an Integrated Program for Water - Resource Systems, Simulation, pp. 13-18, (July 1972).

23. Butz, B. P. et al., Computer-Aided Analysis of Estuarine Dynamics Simulated by a Distributed Parameter Model, IEEE Transactions on Systems, Vol. SMC-3, No. 4, pp. 318-327, (July 1973).

24. Cleary, R. W. et al., Unsteady State, Three-Dimensional Model of Thermal Pollution in Rivers, AIChE, Vol. 69, no. 129, pp. 422-431, (1972).

25. Rains, B. A. and Flick, R. S., Water Quality Monitoring on the Mississippi River has its Pitfalls, AIChE, Vol. 69, no. 129, pp. 401-413, (1972).

26. Rogs, L. W. and Pecoraro, J. N., Pollution Solutions? A Look at NASA Space R&D Could Supply Answers, ASME, pp. 8-136, (January 1973).

27. O'Connor, D. J. and Mancini, J. L., Water Quality Analysis of the New York Harbor Complex, Journal WPCF, Vol. 44, no. 11, pp. 2129-2139, (Nov. 1972).

28. Nader, J. S., Developments in Sampling and Analysis Instrumentation for Stationary Sources, APCA, Vol. 23, no. 7, pp. 587-591, (July 1973).

29. Fink, D. J., Monitoring Earth's Resources from Space, Technology Review, pp. 32-41, (June 1973).

30. Greenberg, M. R. and Zimmerman, R., Estimating Industrial Water Pollution in Small Regions, Journal WPCF, Vol. 45, no. 3, pp. 462-469, (March 1973).

31. Hill, H. M. and Bergsima, J., Physical System Modeling as a Tool in Resource Planning, Engineering Journal, pp. 26-30, (September 1973).

APPENDIX C

PERSONS INTERVIEWED

Appendix C: Persons Interviewed

F. L. Doyle, Geological Survey of Alabama (UAH)

B. J. Schroer, Center for Environmental and Energy Studies (UAH)

K. E. Johnson, Center for Environmental and Energy Studies (UAH)

L. M. Rosing, University of Alabama in Huntsville

S. Countess, Public Works Department, City of Huntsville

J. Howell, Tennessee Valley Authority, Norris, Tennessee

J. Frey, Tennessee Valley Authority, Muscle Shoals, Alabama

R. Imhoff, Tennessee Valley Authority, Muscle Shoals, Alabama

W. Powell, U.S. Geological Survey, Tuscaloosa, Alabama

J. Hagens, U.S. Environmental Protection Agency, Athens, Georgia

R. Estes, U.S. Environmental Protection Agency, Athens, Georgia

W. Holsomback, U.S. Environmental Protection Agency, Athens, Georgia

T. Miller, Engineering Experiment Station, Georgia Institute of Technology, Atlanta, Georgia

T. Britton, Department of Administrative Services, State of Georgia, Atlanta, Georgia

J. Brown, University of North Alabama, Florence, Alabama

APPENDIX D

EXCERPTS FROM ALABAMA WATER QUALITY CRITERIA

APPENDIX D

EXCERPTS FROM ALABAMA WATER QUALITY CRITERIA

Fish and Wildlife

Best Usage of Waters: Fishing, propagation of fish, aquatic life and wildlife and any other usage except for swimming and water-contact sports or as a source of water supply for drinking or food - processing purposes.

Conditions Related to Best Usage: The waters will be suitable for fish, aquatic life and wildlife propagation. The quality of salt and estuarine waters to which this classification is assigned will also be suitable for the propagation of shrimp and crabs.

Items	Specifications
1. Sewage, industrial wastes or other wastes	None which are not effectively treated in accordance with Section VI of these criteria.
2. pH	Sewage, industrial wastes or other wastes shall not cause the pH to deviate more than one unit from the normal or natural pH nor be less than 6.0 nor greater than 8.5. For salt waters and estuarine waters to which this classification is assigned, wastes as herein described shall not cause the pH to deviate more than one unit from the normal or natural pH nor be less than 6.5 nor greater than 8.5.
3. Temperature	The maximum temperature rise above natural temperatures before the addition of artificial heat shall not exceed 5°F in streams, lakes, and reservoirs nor shall the maximum water temperature exceed 90°F, except that in the Tennessee River Basin and portions of the Tallapoosa River Basin which have been designated by the Alabama Department of Conservation as supporting smallmouth bass, sauger, and walleye, the temperature shall not exceed 86°F. In lakes and reservoirs, there shall be no withdrawals from or discharge of heated waters to the hypolimnion unless it can be shown that such discharge

3. **Temperature (continued)**

will be beneficial to water quality. In all waters the normal daily and seasonal temperature variations that were present before the addition of artificial heat shall be maintained.

The discharge of any heated wastes into any coastal or estuarine waters shall not raise water temperatures more than 4°F above natural during the period October through May nor more than 1.5°F above natural for the months June through September. There shall be no thermal block to the migration of aquatic organisms.

In the application of temperature criteria referred to above, temperature shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth, temperature criteria will be applied at mid-depth.

4. **Dissolved Oxygen**

For a diversified warm water biota, including game fish, daily dissolved oxygen concentrations shall not be less than 5 mg/l at all times, except under extreme conditions due to natural causes it may range between 5 mg/l and 4 mg/l, provided that the water quality is favorable in all other parameters. The normal seasonal and daily fluctuations shall be maintained above these levels. In no event shall the dissolved oxygen level be less than 4 mg/l due to discharges from existing impoundments. All new impoundments shall be designed so that the discharge will contain at least 5 mg/l dissolved oxygen where practicable and technologically possible. The Environmental Protection Agency in cooperation with the State of Alabama and parties responsible for impoundments, shall develop a program to improve the design of existing facilities.

In coastal waters surface dissolved oxygen concentrations shall not be less than 5 mg/l except where natural phenomena cause the value to be depressed.

4. **Dissolved Oxygen (continued)**	In estuaries and tidal tributaries dissolved oxygen concentrations shall not be less than 5 mg/l except in dystrophic waters or where natural conditions cause the value to be depressed.
5. **Toxic substances attributable to sewage, industrial wastes, or other wastes.**	Only such amounts, whether alone or in combination with other substances as will not be injurious to fish and aquatic life including shrimp and crabs in estuarine and salt waters or adversely affect the propagation thereof; impair the palatability or marketability of fish and wildlife or shrimp and crabs in estuarine and salt waters; unreasonably affect the aesthetic value of waters for any use under this classification.
6. **Taste, odor and color producing substances attributable to sewage, industrial waste, and other wastes**	Only such amounts, whether alone or in combination with other substances as will not be injurious to fish and aquatic life including shrimp and crabs in estuarine and salt waters or adversely affect the propagation thereof; impair the palatability or marketability of fish and wildlife or shrimp and crabs in estuarine and salt waters; unreasonably affect the aesthetic value of waters for any use under this classification.
7. **Bacteria**	Bacteria of the fecal coliform group shall not exceed a geometric mean of 1,000/100 ml on a monthly average value; nor exceed a maximum of 2,000/100 ml in any sample. The geometric mean shall be calculated from no less than five samples collected at a given station over a 30-day period at intervals not less than 24 hours. The membrane filter counting procedure will be preferred, but the multiple tube technique (five-tube) is acceptable.
8. **Radioactivity**	The concentrations of radioactive materials present shall not exceed the radiation protection guides recommended by the Criteria and Standards Division, Office of Radiation Protection, EPA (formerly Federal Radiation Council).

9. **Turbidity**

There shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Jackson units above background. Background will be interpreted as the natural condition of the receiving waters without the influence of manmade or man induced causes. Turbidity levels caused by natural runoff will be included in establishing background levels.

Agricultural and Industrial Water Supply

Best Usage of Waters: Agricultural irrigation, livestock watering, industrial cooling and process water supplies, fish survival and any other usage, except fishing, bathing recreational activities including water-contact sports or as source of water supply for drinking or food-processing purposes.

Conditions Related to Best Usage: The waters, except for natural impurities which may be present therein, will be suitable for agricultural irrigation, and livestock watering, industrial cooling waters and fish survival. The waters will be usable after special treatment, as may be needed under each particular circumstance, for industrial process water supplies. The waters will also be suitable for other uses for which waters of lower quality will be satisfactory.

Items	Specifications
1. Sewage, industrial wastes or other wastes..	None which are not effectively treated or controlled in accordance with Section VI of these criteria.
2. pH	Sewage, industrial waste or other wastes shall not cause the pH to deviate more than one unit from the normal or natural pH nor be less than 6.0 nor greater than 8.5.
3. Temperature	The maximum temperature rise above natural temperatures before the addition of artificial heat shall not exceed 5°F in streams, lakes, and reservoirs nor shall the maximum water temperature exceed 90°F, except that in the Tennessee River Basin and portions of

3. Temperature (continued)

the Tallapoosa River Basin which have been designated by the Alabama Department of Conservation as supporting smallmouth bass, sauger, and walleye, the temperature shall not exceed 86°F. In lakes and reservoirs, there shall be no withdrawals from or discharge of heated waters to the hypolimnion unless it can be shown that such discharge will be beneficial to water quality. In all waters the normal daily and seasonal temperature variations that were present before the addition of artificial heat shall be maintained.

The discharge of any heated wastes into any coastal or estuarine waters shall not raise water temperatures more than 4°F above natural during the period October through May nor more than 1.5°F above natural for the months June through September. There shall be no thermal block to the migration of aquatic organisms.

In the application of temperature criteria referred to above, temperature shall be measured at a depth of 5 feet in waters 10 feet or greater in depth; and for those waters less than 10 feet in depth temperature criteria will be applied at mid-depth.

4. Dissolved Oxygen

Sewage, industrial waste or other wastes shall not cause the dissolved oxygen to be less than 2.0 parts per million as measured at a depth of five feet in waters ten feet or greater in depth and at mid-depth in waters less than ten feet in depth.

5. Color, odor and taste producing substances, toxic substances, and other deleterious substances, including chemical compounds, attributable to sewage, industrial wastes and other wastes.

Only such amounts as will not render the waters unsuitable for agricultural irrigation, livestock watering, industrial cooling, industrial process water supply purposes and fish survival.

6. **Radioactivity**

The concentrations of radioactive materials present shall not exceed the radiation protection guides recommended by the Criteria and Standards Division, Office of Radiation Protection, EPA (formerly Federal Radiation Council).

7. **Turbidity**

There shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters or interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Jackson units above background. Background will be interpreted as the natural condition of the receiving waters without the influence of manmade or man induced causes. Turbidity levels caused by natural runoff will be included in establishing background levels.

Navigation

Best Usage of Waters: Navigation

Conditions Related to Best Usage: Waters will be of a quality suitable for navigation and any other uses except agricultural irrigation, livestock watering, industrial cooling, industrial process, water supply, fish and wildlife propagation, recreational activities including swimming and skiing, or source of water supply for drinking or food-processing purposes.

Items	Specifications
1. Sewage, industrial wastes or other wastes.	None which are not effectively treated or controlled to the best practicable degree.
2. pH	Sewage, industrial wastes or other wastes shall not cause the normal or natural pH to be lower than 5.0 nor greater than 9.5.
3. Dissolved oxygen	Sufficient to prevent the development of an offensive condition.
4. Odor producing substances	Only in such amounts as will not create an offensive condition.
5. Radioactivity	The concentrations of radioactive materials present shall not exceed the radiation protection guides recommended by the Criteria and Standards Division, Office of Radiation Protection, EPA (formerly Federal Radiation Council).
6. Turbidity	There shall be no turbidity of other than natural origin that will cause substantial visible contrast with the natural appearance of waters of interfere with any beneficial uses which they serve. Furthermore, in no case shall turbidity exceed 50 Jackson units above background. Background will be interpreted as the natural condition of the receiving waters without the influence of manmade or man induced causes. Turbidity levels caused by natural runoff will be included in establishing background levels.

APPENDIX E

GEORGIA TECH REMOTE DATA ACQUISITION SYSTEM (RDAS)

APPENDIX E:

Brief Description of Georgia Tech Remote Data Acquisition System (RDAS)*

This document describes a prototype remote data acquisition system designed for use in the automatic collection and monitoring of environmental pollution data. The Remote Data Acquisition System (RDAS) described herein was developed by the Georgia Tech Engineering Experiment Station under contract with the Department of Administrative Services, State of Georgia. The salient features of the RDAS are a direct result of valuable technical assistance provided by personnel in the Air Quality Evaluation Service, Department of Human Resources, and by personnel in the Scientific Computer Center, DOAS.

The RDAS is a special purpose digital system which serves as the interface between remotely located pollution sensors and telephone lines linking the remote site with the Central Control Station (CCS). Electrical signals generated by up to eight sensors comprise the data inputs to the RDAS. These signals are conditioned and sampled at a rate such that 256 samples are taken for each sensor every five minutes. The samples are converted from analog to digital form (eight binary bits) and averaged to yield the arithmetic mean of each signal for every five minute period. The average data are stored on magnetic tape and displayed in hard copy form by a digital printer. On command from the CCS, the averaged data stored on the magnetic tape are transmitted to the CCS (typically, once every 24 hours); in addition, real time (unaveraged)data may also be sent to the CCS on command. The RDAS also monitors the data inputs and notifies the CCS if any input exceeds its preset threshold value. The RDAS automatically performs the functions of data acquisition, monitoring, averaging, storage, and recording; the transmission of data is controlled by the CCS.

The interface between the RDAS and telephone line is provided by a Telco 103 data set and 801 Automatic Calling Unit (ACU). Data transmission between RDAS and CCS is done at 300 baud, asynchronously. The RDAS provides the necessary signals to interact with these two Telco devices.

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* Excerpt of writeup received through Mr. Ted Britton, Department of Administrative Services, State of Georgia.

An Addmaster digital printer (with serial BCD input) provides a hard copy record of the averaged data. The printer is an external device and not considered to be a part of the RDAS proper; however, the RDAS provides the necessary signals to control the operation of the Addmaster printer.

The RDAS relies on instructions received from the CCS to control the transfer of data acquired and processed by the RDAS. There is provision for ten distinct instructions; however, only eight are used by this version of the RDAS and are described in detail in Section II.

Circuit diagrams, wire lists, and parts lists are presented in Section III.